

PB-217 423

**WATER QUALITY CONTROL STUDY THE FRYINGPAN
ARKANSAS PROJECT ARKANSAS RIVER SUBBASIN
COLORADO**

**Federal Water Pollution Control Administration
Dallas, Texas**

October 1968

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PB 217 423



**WATER QUALITY CONTROL STUDY
THE FRYINGPAN ARKANSAS PROJECT
ARKANSAS RIVER SUBBASIN
COLORADO**

**A Study of Needs and Value of Storage
For
Water Quality Control**

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**UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Dallas, Texas**

OCTOBER 1968

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WATER QUALITY CONTROL STUDY
THE FRYINGPAN ARKANSAS PROJECT
ARKANSAS RIVER SUBBASIN
COLORADO

Abstract

A survey has been made which discloses that it would be desirable to provide storage for streamflow regulation for the purpose of water quality control in the Arkansas River subbasin above John Martin Reservoir. Provision of storage in the Fryingpan Arkansas Project for this purpose was considered, however it was concluded that alternative uses of the water resources available from this project would make a greater contribution to the economy of the nation. It was found that water pollution control problems could be solved by modifying basin waste disposal practices and by providing storage in projects other than the Fryingpan Arkansas Project for flow regulation.

Prepared for
U. S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Region 7, Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Dallas, Texas

OCTOBER 1968

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I. INTRODUCTION

Request and Authority

In a meeting of April 28, 1964, and subsequent letter of May 8, 1964, the Bureau of Reclamation, Region 7, Denver, Colorado, requested the Public Health Service to determine the need for and value of storage of water in the reservoirs of the proposed Fryingpan-Arkansas Project for the purpose of streamflow regulation for water quality control.

The subsequent study was made in accordance with provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.) wherein authority is given to conduct investigations relating to the causes, control, and prevention of water pollution.

Effective December 31, 1965, Section 2 of the Water Pollution Control Act, as amended by Public Law 89-234, established the Federal Water Pollution Control Administration as an operating Agency of the Department of Health, Education and Welfare. Under Reorganization Plan No. 2 of 1966, the Administration was transferred to the Department of the Interior, effective May 10, 1966. As a result of these changes, responsibility for completing this study was transferred to the Federal Water Pollution Control Administration in the U. S. Department of the Interior.

Purpose and Scope

The purpose of this study was to appraise water requirements to the year 2070 for water quality control purposes in the Arkansas River basin above John Martin Reservoir, and to determine the need for and value of storage of water in the reservoirs of the proposed Fryingpan-Arkansas Project in the Arkansas River Basin, for the purpose of streamflow regulation for controlling water quality. The results presented are based on projected economic developments and anticipated needs for preservation of water quality in streams in the study area.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in the assembly of data for this report are gratefully acknowledged. Special appreciation is expressed to the following:

1. Economic Research Service of U. S. Department of Agriculture, Fort Collins, Colorado
2. Bureau of Mines, Denver, Colorado
3. Geological Survey, Denver, Colorado
4. Bureau of Reclamation, Pueblo and Denver, Colorado
5. Corps of Engineers, Albuquerque, New Mexico
6. Colorado Water Pollution Control Commission, Denver, Colorado
7. Colorado State Department of Health, Denver, Colorado
8. Colorado Division of Commerce and Development, Denver, Colorado
9. Colorado Agricultural Experiment Stations, Hydraulic Laboratory, Fort Collins, Colorado
10. Colorado School of Mines, Golden, Colorado
11. Business Research Division, University of Colorado, Boulder, Colorado
12. Colorado Office of State Planning, Denver, Colorado
13. Colorado State University, Engineering Research Institute, Fort Collins, Colorado
14. Colorado Department of Agriculture, Denver, Colorado
15. Officials of cities in the study area
16. Representatives of industry in the study area

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Findings

1. The study area comprises the 13 counties of the Arkansas River basin in Colorado above John Martin Reservoir. In 1960 the population of this area was 367,000. Approximately 265,000 or 72 percent of the population was located in or near 11 urban communities. The total 1960 rural population in the study area was 102,000.

2. Waste production in the study area is largely centered in the areas of Pueblo, Colorado Springs, Canon City, La Junta, Security, and Trinidad. Smaller but substantial quantities of waste production occur in the vicinities of Leadville, Salida, Walsenburg, Rock Ford, and Las Animas.

3. Municipal waste discharges to study area streams are estimated to be between 40 to 50 mgd with a population equivalent (PE) of about 60,000. Biochemical oxygen demand (BOD) removal from wastes is estimated to be from 60 to 90 percent. However, the majority of the waste treatment plants provide secondary treatment with BOD removal approaching 90 percent. Principal sources of industrial waste discharges are the iron and steel, food and kindred products and mining industries.

4. Acid mine drainage, largely attributed to abandoned mines, is evident in the area of Leadville. Noticeable concentrations of heavy metals potentially harmful to the stream and its environment have been observed in California Gulch, tributary to the Arkansas River near Leadville and in the river itself immediately below this point. Also, acids are released from exposed mineral deposits at the head of the South Fork of Lake Creek frequently depressing the pH of the water below 5.0.

5. Severe mineral pollution of the Arkansas River and tributaries below Pueblo results from the return of salt laden irrigation water to the streams. Return flows frequently raise the dissolved solids concentrations above 2,000 mg/l in the Arkansas River.

Conclusions

1. Water quality in the Arkansas River and most tributaries below Pueblo is not suitable for municipal and many industrial water uses because of excessive mineral concentrations. However, it does not appear that a reduction of mineral levels is necessary to maintain stream uses established by state water quality standards.

2. If current irrigation practices persist with resultant present levels of mineral pollution, even with complete regulation of the water resources in the study area, it would not be practicable to maintain the mineral quality of the water in the Arkansas River below Pueblo within a range suitable for municipal use or industrial process uses by streamflow regulation. If reduction of mineral concentrations are desired to change the use of the stream from that established by the State of Colorado Water Quality Standards, reduction of mineral waste contribution to the stream will be necessary as discussed in the body of this report.

3. Due to the limited supply, it appears that optimum development of the water resources of the study area will eventually require that all of the better quality (low mineral concentration) water be first used to satisfy municipal and industrial processing water needs and later be reclaimed for other uses, such as irrigation and industrial cooling. Diversion of water of acceptable quality from the Arkansas River above Pueblo for satisfying study area municipal and industrial water requirements is considered more practical than attempting to improve the mineral quality in the river below Pueblo by flow regulation to provide a local source for satisfying a portion of these requirements.

4. By 2040 it is anticipated that the entire flow of the Arkansas River above Pueblo will be needed for municipal and industrial water supplies and will not be available for direct release to the river channel below Pueblo for quality control. River flow below Pueblo will then be formed by tributary inflow municipal and industrial waste water, and irrigation return flows.

5. It is anticipated that alternative uses of the water resources provided by the Fryingpan Arkansas Project would make a greater contribution to the economy of the nation than their use for quality control. Therefore, benefits assigned to any storage provided for quality control in any reservoir in the project would be limited to the sum of the direct benefits resulting from use of the stored water within the multiple purpose reservoirs.

6. Throughout the study period (1970-2070), provision of adequate waste treatment considered to be well operated secondary treatment achieving at least 90 percent removal of BOD, will probably be sufficient to maintain acceptable dissolved oxygen concentrations in study area streams, except for the Arkansas River below Pueblo and Fountain Creek below Colorado Springs.

7. With treatment facilities capable of removing 90 percent of the BOD from wastes produced and with anticipated increasing use of water resources above Pueblo for municipal and industrial water supplies, it appears that anticipated releases from Pueblo Reservoir will be adequate to maintain dissolved oxygen concentrations above 4 mg/l in the Arkansas River below Pueblo until about 2030. Advanced waste treatment facilities (facilities that will remove more than 90 percent of the BOD of the waste), flow regulation or a combination of both, will then be needed. By 2070, it is estimated that supplemental flows totaling 85,000 acre-feet of water per year will be needed from tributary reservoirs below Pueblo unless higher levels of treatment are provided. The combined yields (92,100 acre-feet per year) of potential reservoirs (Pleasant View, Welton, Apishapa, Timpas, and Adobe) considered in our analysis of basin resources but not included in the Fryingpan-Arkansas Project, could satisfy these needs through the terminal year (2070) of this study.

8. To maintain dissolved oxygen concentrations above 4 mg/l in Fountain Creek, advanced waste treatment facilities or a combination of advanced waste treatment and flow regulation will be needed. By 2070, it is estimated that supplemental flows totaling 127,000 acre-feet per year would be needed unless higher levels of treatment are provided. Potential reservoirs (Ute Pass and Fountain Creek), considered in our analysis of basin resources but not included in the Fryingpan-Arkansas Project, could yield only about 45,800 acre-feet per year.

9. Our studies comparing advanced waste treatment costs with flow regulation costs indicate that maximum use of flow regulation by construction of reservoirs and release of stored waters would likely provide the most economical method for water quality control in both Fountain Creek and the Arkansas River below Pueblo.

10. While appropriation of water for storage to be used exclusively for quality control in study area streams is not considered possible due to the scarcity of water resources, it does not appear impossible to develop flow regulating facilities that would provide supplemental flows where required for quality control through dual use of the available resources. Studies should be continued in cooperation with state agencies to develop a comprehensive plan for regulation of flow throughout the basin to gain optimum use of the limited resources available and to develop the legal base for implementation of the plan.

III. PROJECT DESCRIPTION

The Fryingpan-Arkansas Project, authorized by Congress in 1962 has been developed for the collection and transmountain diversion of water from the Fryingpan and other tributaries of the Roaring Fork River in Western Colorado to the Arkansas River in Eastern Colorado.

Waters to be diverted to the Arkansas Valley originate from melting snows on the high mountains bordering the Roaring Fork and Fryingpan Rivers.

The plan includes construction of two new reservoirs -- Ruedi Reservoir on the western slope just above the town of Basalt on the Fryingpan River, and Pueblo Reservoir on the eastern slope just above the city of Pueblo on the Arkansas River. Ruedi Reservoir will provide replacement storage such that stored waters may be released downstream to satisfy the requirements of prior-right holders when project diversions are made. The plan also involves enlargement of the existing Sugar Loaf and Twin Lakes Reservoirs and construction of a power system including two power plants and a connecting canal. A pipeline is also proposed to transport water from the Pueblo Reservoir to service areas below the reservoir for municipal and industrial supplies.

The project as proposed and delineated on figure III-1 will provide additional conservation and regulation of native waters of the Arkansas River and will import approximately 69,200 acre-feet annually from the Colorado River Watershed. The project water supply will be utilized to supplement the present irrigation and municipal supplies and for the generation of hydroelectric energy. It will provide about 20,500 acre-feet annually for municipal and industrial purposes and will make available, approximately 163,000 acre-feet of new and return flow water annually to supplement the present irrigation water supply on approximately 280,600 acres in the Southeastern Water Conservancy District during the growing season. Construction began on the first unit (Ruedi Dam) of the project in July 1964. The first partial diversion of water is expected in the spring of 1970 and final completion of the entire diversion system is expected about 1974.

IV. STUDY AREA DESCRIPTION

Location and Boundaries

As shown in figure III-1, the study area encompasses the Arkansas River drainage basin above John Martin Reservoir in southeastern Colorado, and includes 13 counties lying partially within or bordering the basin. The area approximates the southeast quarter of the State of Colorado. The study area was divided into the three subareas shown on figure III-1. They are as follows: Area I - Huerfano, Custer, Fremont, Chaffee, Lake, Park, and Teller Counties; Area II - Pueblo and El Paso Counties; Area III - Las Animas, Otero, Crowley, and Bent Counties. Area I, in essence, is the mountainous area; Area II is the metropolitan areas, and Area III is the plains or lower valley area.

Geography and Topography

The Arkansas River basin in Colorado can best be described as a Great Plains area bounded on the west by the eastern face of the Rocky Mountains, east of which is a belt of foothills running generally north and south. Originating in the snowcapped mountains of Lake County, the river parallels the Continental Divide for a distance of 70 miles, and then turns eastward flowing through a relatively narrow canyon until it emerges through the deep Royal Gorge at Canon City. From Canon City to Pueblo, the river flows through a narrow valley flanked by foothills. Below Pueblo, the river valley widens appreciably and traverses the high plains area of southeastern Colorado. Along the Arkansas River and most of its tributaries, the lands occur as river bottom land, terraces or benches, and alluvial fans. The uplands are residual soils derived from shale limestone or sandstone, except in some areas where alluvial outwash overlies the residual soil.

Types of vegetation are numerous and vary from alpine type flora around mountain peaks to various species of grass and cacti in the lower regions. At the lower elevations, pinon pine, juniper, scrub oak, and brush occur frequently along rocky ridges and some of the rugged canyons while cottonwood trees, willows, and various types of brush are found in the flatter areas along the many water courses.

The elevation of the study area ranges from over 14,000 feet in the mountainous area to about 4,000 feet at the John Martin Reservoir. From the foot of the mountains to Pueblo, the average fall of the Arkansas Valley is about 18 feet per mile, while downstream from Pueblo, it averages 7½ feet per mile. Principal tributaries entering from the north side of the river are: Oil Creek, Beaver Creek,

Fountain Creek, Chico Creek, Horse Creek, and Adobe Creek. The larger south side streams are the St. Charles River, Huerfano River, Apishapa River, and Purgatoire River.

Climate

The study area has two general types of climatic conditions. From the John Martin Reservoir to Canon City near the foot of the Rocky Mountains, the climate is semi-arid. The mean annual temperature in this area is 52°F., varying from an average of 29°F. in January to a mean of 79°F. in July. Extreme temperatures from minus 54°F. to 114°F. have been recorded in the area.^{1/} In the mountains, the climate varies from arid to subhumid within relatively short distances. The summers are cool and the winters long and severe.

Much of the total precipitation at high elevations is in the form of snow. Runoff from this snowfall is a maximum in late spring and early summer months and constitutes most of the dependable water supply for downstream areas for municipal, industrial, irrigation, and other beneficial uses. Average annual precipitation in the basin varies from about 18 inches at Leadville to 12 inches at Pueblo, and 16 inches near the Colorado-Kansas border.^{2/} Most of the precipitation falls during the growing season but is considered inadequate^{2/} for successful crop production. The average growing season ranges from 82 days near Leadville to 167 days near the lower end of the study area.

Principal Communities and Industries

The study area is sparsely populated and predominately rural in character except in and around the Pueblo and Colorado Springs metropolitan areas. Outside of these areas there were only four towns with 1960 populations in excess of 5,000^{3/} A list of principal study area communities is presented in table IV-1 by county and stream location. The cities of Lamar and Eads, although outside the study area, are included in the table since the proposed project will provide municipal and industrial water supplies for the cities.

With a large diversified steel plant on the southern outskirts of the city, and many manufacturing companies oriented to the primary metals, the city of Pueblo is considered the manufacturing hub of the region. A few miles west of the city in Fremont County are several other manufacturing concerns including a major producer of bulk cement, a manufacturer of gypsum wallboard, and one of the Nation's largest suppliers of "scientific" toy rocket engines. Long an important railhead for transshipment of precious metals, Pueblo is the transportation center of the study area. The city is also the home of a U. S. Army Ordnance Depot, the Colorado State Hospital, and the State Fair.

Table IV-1

Principal Study Area Communities

<u>County</u>	<u>Town</u>	1960 <u>Population</u>	<u>Stream Location</u>	Approx. <u>(River Mile)</u>
Lake	Climax	1,609	East. Fk. Ark. River	(1,459)
	Leadville	4,008	Arkansas River	(1,444)
Chaffee	Buena Vista	1,806	Arkansas River	(1,409)
	Salida	4,560	Arkansas River	(1,385)
Fremont	Canon City	11,979 <u>a/</u>	Arkansas River	(1,331)
	Florence	2,821	Arkansas River	(1,325)
Pueblo	Pueblo	103,336 <u>b/</u>	Arkansas River	(1,290)
El Paso	Colorado Springs	100,220 <u>b/</u>	Fountain Creek	(49)
	Security	9,017	Fountain Creek	(35)
Huerfano	Walsenburg	5,071	Cucharas River	(28)
Otero	Fowler	1,240	Arkansas River	(1,234)
	Rocky Ford	4,929	Arkansas River	(1,215)
	La Junta	8,026	Arkansas River	(1,198)
Crowley	Ordway	1,254	(near)Arkansas River	(1,220)
Bent	Las Animas	3,402	Arkansas River	(1,177)
Las Animas	Trinidad	10,691	Purgatoire River	(157)
Prowers	Lamar <u>c/</u>	7,369	Arkansas River	(1,150)
Kiowa	Eads <u>c/</u>	929		

a/ Includes East Canon City and Lincoln Parkb/ Includes Urban Fringe Areasc/ City is not in study area but will be supplied water from study area

Colorado Springs, best known as a tourist center, is becoming important as an electronic and industry research complex. The U. S. Air Force Academy is located on the outskirts of the city.

While manufacturing is well established in the study area, principal industrial activities of the area are centered around agriculture and mining. Irrigation farming is widespread in the valleys of the Arkansas River and its tributary streams. Dryland farming is practiced on the more remote unirrigable lands of the high plains. Livestock raising and dairy farming are carried on in conjunction with other farming. Principal crops include grains (chiefly wheat, sorghums, and field beans), sugar beets, forage, fruit, and truck crops.

Mining, though less extensive than years past, is still a major activity. Formerly an important supplier of gold, silver, copper, and lead, the study area now produces molybdenum (used in the manufacture of steel), beryllium (a glamour metal used in rocket construction), uranium, vanadium, thorium, coal, and a number of other useful minerals.

The tourist industry is a major industry in this area. Trout fishing, pheasant and duck hunting, big game hunting, winter skiing, and many other forms of recreation are available in the study area and are drawing an increasing number of tourists to the area. Many people maintain seasonal homes for these uses.

V. WATER RESOURCES OF THE STUDY AREA

General

The economy of the study area is closely bound to its natural resources. Of these resources none is considered more important or vital to the welfare of the study area, its people, industries, and the development of its other resources than water supply. The importance attached to development of water supplies is indicated by the active work of numerous local, State, and Federal water resource agencies in the area.

The Arkansas River, fed largely by melting snows at its head in the Rocky Mountains and transbasin diversions, is the hydrologic artery of the study area. It is the principal source of water for municipal and industrial water supplies, irrigation, livestock watering, fishing, and other recreational activities.

The direct flow rights of the watercourse and all of its tributaries are greatly over appropriated.

The average flow of the river as it emerges from the mountains is about 700 cubic feet per second (cfs) as compared with total adjudicated direct flow rights downstream to the State line of over 7,000 cfs.^{4/} Tributary over appropriations are even greater.

Flow of the river and its tributaries is used and reused many times before it reaches the Colorado State line. Only the most senior water rights (dating back before the turn of the century in most cases) can divert reasonably adequate supplies of river water, while junior rights can be supplied only at short and intermittent intervals.

On May 1, 1957, the Colorado Legislature enacted a ground water law which provides control over ". . . any water not visible on the surface of the ground under natural conditions."* Under terms of the law, all ground water users were required to register existing wells with the State Engineer. New wells cannot be drilled or the amount of water pumped from existing wells increased without a permit. The Water Resources Division of the U. S. Geological Survey in cooperation with the Colorado Water Conservation Board and the Southeastern Water Conservancy District is presently making ground water studies of southeastern Colorado (which includes the study area) to determine ground water yields and effects of withdrawals on surface water and vice versa.

* Colorado Revised Statutes, Sections, 147-19-1 to 147-19-15.

Quantity of Water Available

Ground Water

There are three major aquifers in the Arkansas River basin in Colorado. These include: The valley fill in the valleys of the Arkansas River and its major tributaries, the Ogallala formation which is a superficial deposit of unconsolidated materials underlying the High Plains, and the Dakota sandstone which is a bedrock formation underlying the major portion of the Arkansas River basin in Colorado east of the foothills.

The valley fill is the most productive aquifer in the Arkansas River basin in Colorado. It consists largely of saturated sand and gravel and will yield water freely to wells. Yields of large capacity wells in the valley fill range from a few hundred gallons per minute to nearly 3,000 gallons per minute (gpm), average yield is about 600 gpm. The aquifer is hydraulically connected with the river and ground water and surface water constitute a common supply. The usable ground water in storage in the aquifer from Pueblo to the State line is about 1 million acre-feet.^{5/}

The Ogallala formation occurs at only a few locations in the study area, in parts of El Paso, Pueblo, and Crowley Counties. Much of the formation in this area is largely drained of water although in most places there is enough water for domestic and stock uses, and in a few places enough for irrigation.

The Dakota sandstone is a dependable source of domestic and stock supplies throughout a large part of the Arkansas River basin in Colorado. The formation underlies almost all of the lower half of the study area. Large capacity wells have been developed in the formation with yields ranging from a few hundred gallons a minute to more than 3,000 gpm. A number of deep wells supply water from the formation in eastern Fremont County.

Today approximately 1,400 large-capacity wells are pumped in the Arkansas River basin between Pueblo and the State line, nearly all of which are below irrigation canals and are used to supplement canal deliveries. Development of the ground water reservoir has resulted in increased beneficial use of water by supplying late season needs in all years as well as major needs during low-runoff years.^{6/} Calculated 1964 pumpage for all uses in the study area was approximately 665,000 acre-feet.^{7/}

Surface Water

Since measurements of streamflow at points on the main stem of the Arkansas River in Colorado have been necessary for the

administration of water rights for diversion along the river, gaging stations have long been maintained and operated at various locations between the headwaters of the river and the Colorado - Kansas State line. An analysis of streamflow on the Arkansas River main stem is shown on figure A-1 in Appendix A.

Streamflow at Canon City which has averaged about 700 cfs over the past 76 years, represents the major contribution of the mountainous headwaters section of the river. This flow is largely composed of melting snows and transmountain diversions which have been made throughout most of the period-of-record. Streamflow at Canon City receives some regulation by existing upstream tributary impoundments and is the amount remaining in the river after the consumptive use incident to the irrigation of some 47,000 acres of land above Canon City located principally on tributaries.

Between Canon City and the State line, the river provides water for the irrigation of about 400,000 acres¹⁷ of land supplied by diversions from the main stem, and water for use at Pueblo for municipal and industrial water supply purposes. Average annual diversions below Canon City for the period 1955 to 1964 totaled 1,578,384 acre-feet.¹⁷ Intervening tributaries furnish water supplies to lands irrigated from them, and their discharges reaching the main stem are significant only during peak runoff periods or immediately following summer rain storms.

Streamflow in the study area portion of the Arkansas River and its tributaries fluctuates widely. During the 76-year period of record at Canon City, a maximum discharge of 19,000 cubic feet per second (cfs) was recorded on August 2, 1921, and a minimum of 69 cfs on May 13, 1959.¹⁷

Although limited in some instances, adequate tributary streamflow data is available. The salient points of this data are compiled in table V-1. Flow duration curves constructed from these data are shown by figure A-2, Appendix A.

Thirteen reservoirs with storage capacities in excess of 5,000 acre-feet are now located in the study area. These are shown on figures III-1 and in table V-2. Only one reservoir, the Corps of Engineers John Martin Reservoir on the Arkansas River near the Colorado - Kansas State line exceeds 100,000 acre-feet storage capacity.

Study area surface water resources are presently supplemented by nine transbasin diversion projects with total diversions averaging about 50,000 acre-feet per year. See table V-3 and figure III-1. In addition, the city of Colorado Springs in joint venture with the city of Aurora (outside the study area) has under construction the

Table V-1

Streamflow Data - Selected Watersheds

<u>Watershed or Tributary</u>	<u>Project(s)</u>	<u>Gaging Station Name</u>	<u>Years of Record (Water Year)</u>	Flow - cfs Mean Monthly (Max) Mean Annual Mean Monthly (Min)
Fountain Creek	Ute Pass	Colorado Springs	1958-1963	2.6 10.8 0.37
	Fountain Creek	Pueblo	1940-1963	602.0 54.2 1.99
St. Charles River	Pleasant View	Pueblo	1941-1953	790.0 39.2 0.26
Huerfano River	Welton	Undercliffe	1939-1963	118.2 39.2 0
Cucharas River		La Veta	1938-1963	19.8 25.0 0.27
Apishapa River	Apishapa	Fowler	1939-1963	48.9 33.7 0.07
Timpas Creek	Timpas	Rocky Ford	1941-1950	154.0 47.4 2.3
Adobe Creek	Adobe	--	--	- 3.0 a/ -
Purgatoire River	Purgatoire	Las Animas	1947-1963	237.0 93.1 0.07
		Trinidad	1922-1960	106.4 87.5 0.31

a/ Estimate based on runoff characteristics of adjoining area.

Source: Geological Survey 8/, and Colorado Division of Commerce and Development 7/

Table V-2

Existing Reservoirs in the Study Area ^{a/}

<u>Reservoir</u>	<u>Location</u>	<u>Ownership</u>	<u>Usable Conservation Storage (ac.-ft.)</u>	<u>Total Storage Capacity (ac.-ft.)</u>
Sugar Loaf	Lake Fork	Private	17,370	17,370
Twin Lakes	Lake Creek	Private	54,900	112,500
Clear Creek	Clear Creek	Private	11,440	11,440
Cucharas	Cucharas River	Private	21,000	40,210
Horse Creek	Horse Creek (Offstream)	Private	25,000	29,000
Adobe Creek	Adobe Creek (Offstream)	Private	64,900	71,000
Model	Purgatoire River (Offstream)	Private	6,200	20,350 ^{b/}
John Martin	Arkansas River	Corps	363,945	631,120
Lake Meredith	Arkansas River (Offstream)	Private	26,000	26,000
Lake Henry	Arkansas River (Offstream)	Private	6,300	9,916
Dye Lake	Arkansas River (Offstream)	Private	7,990	^{c/}
Holbrook No. 1	Arkansas River (Offstream)	Private	7,420	^{c/}
CF & I No. 3	Arkansas River (Offstream)	Private	8,530	^{c/}

^{a/} Reservoirs with storage capacity total in excess of 5,000 acre-feet.

^{b/} 20,000 acre-feet of storage will be transferred to conservation storage in the authorized Trinidad Reservoir.

^{c/} Information not available.

Source: Bureau of Reclamation ^{2/}, and Federal Power Commission ^{10/}

Table V-3

Existing Transbasin Diversion Projects a/

<u>Project Name</u>	<u>Period of Diversion Record (years)</u>	<u>Average Annual Diversion (Ac.-Ft.)</u>	<u>Diversions Oct. 1962-Sept. 1963 (Ac.-Ft.)</u>
Fremont Pass Ditch	35	527	None
Columbine Ditch	33	1,023	952 b/
Ewing Ditch	56	1,211	393 b/
Wurtz Ditch	32	2,096	1,569 b/
Busk-Ivanhoe Diversion Tunnel	39	4,444	3,700
Twin Lakes (Independence Pass) Diversion Tunnel	29	35,831	31,940
Larkspur Ditch	29	134	12
Medrano Ditch e/	d/	d/	d/
Hoosier Pass Tunnel e/	12	7,022	9,860

a/ All diversions from Colorado River basin except where noted.

b/ Previously unpublished figures obtained from city of Pueblo.

c/ Diversion from Rio Grande basin.

d/ Information not available.

e/ Diversion to South Platte basin then to Arkansas basin from watershed in Summit County - source of water supply for Colorado Springs.

Source: Bureau of Reclamation 2/

Homestake Reservoir project, a transmountain diversion project, (figure III-1) which will increase the city's water supply by about 33 mgd.

The study area's water resources will be expanded substantially by construction of the four authorized Reservoir Impoundments shown in table V-4. The proposed Trinidad project will be constructed by the Corps of Engineers and provide supplemental water supply for an irrigated area of 19,700 acres below Trinidad, and possible domestic and industrial uses. Sugar Loaf and Twin Lakes enlargements, and Pueblo Reservoir are part of the Fryingpan-Arkansas Project.

Quality of Water Available

The water of the Arkansas River and its tributaries in the headwaters (above Canon City) is generally of excellent chemical quality. Some localized pollution from acid mine drainage occurs in the area of Leadville and is evident in California Gulch (tributary to the Arkansas River near Leadville), and in the Arkansas River for a few miles downstream from this point. Studies are being made by the Fish and Wildlife Service and the Geological Survey to determine the location and extent of pollution (heavy metals) from mine drainage in this area, and the effects of these substances on the stream environment. Upon completion of these studies, it is expected solutions to the control of pollution at or near the source will be developed.

As shown by table V-5, the mineral quality of the Arkansas River becomes progressively worse downstream from Canon City. This is attributed to accumulation of salts from return flows from irrigated lands and from solids picked up from soluble rock strata along the tributary streams.

High mineral concentrations are found in the Arkansas River below the Nepesta water quality gage and in all the major tributaries shown on the table. For all the points listed, except those on the main stem of the Arkansas River above Pueblo and on the Purgatoire River at Trinidad, the dissolved solids exceed the upper limits established in the Public Health Service Drinking Water Standards-1962.^{11/}

However, low mineral concentrations are found near the headwaters of most of the tributaries throughout the study area. Fountain Creek above Monument Creek is now used as a source of water supply by the city of Colorado Springs (see table VII-1). Chemical quality data are not available for the stream at this location, however, dissolved solids concentrations in the city's water supply indicate good chemical quality, well within the upper limits of the above referenced drinking water standards. A summary of the chemical quality of study area municipal surface and ground water supplies is shown in table V-6.

Table V-4

Reservoir Impoundments Associated With
Authorized Water Supply Projects
in the Study Area

<u>Feature Name</u>	<u>Location</u>	<u>Storage Capacity</u>		<u>Ownership</u>	<u>Principal User</u>
		<u>Conservation</u> (ac.-ft.)	<u>Total</u> (ac.-ft.)		
Trinidad	Purgatoire River	20,000	114,500	Corps of Engineers ^{a/}	Flood Control, Conservation
Sugar Loaf ^{b/} (Enlargement)	Lake Fork	121,000	130,000	Bureau of Reclamation	Power, Conservation
Twin Lakes ^{b/} (Enlargement)	Lake Creek	93,192	166,179	Bureau of Reclamation	Power, Conservation
Pueblo ^{b/}	Arkansas River	233,985 ^{c/}	356,821	Bureau of Reclamation	Flood Control, Power, Conservation

^{a/}The Trinidad project would be constructed, operated and maintained by the Corps of Engineers.

^{b/}part of the proposed Fryingpan-Arkansas Project Development.

^{c/}There is 92,799 acre-feet in the joint use pool in addition to the 234,000 acre-feet in the conservation pool.

Source: Bureau of Reclamation ^{2/}

Table V-3

Chemical Character of Surface Waters from Selected Points in the Study Area
(mg/l)

	Arith. Mean Min. Max.	Dissolved Solids (mg/l)		Chlorides (mg/l)		Sulfates (mg/l)		Dissolved Solids (mg/l)		Chlorides (mg/l)		Sulfates (mg/l)	
		177	9	43	34	1213	50	1213	50	1213	50	1213	50
Arkansas River at Canon City Period of Record Nov 1963 - Sep 1964	226	15	3	43	43	2360	59	2360	59	1250	199	1250	199
Arkansas River near Pueblo Period of Record Nov 1963 - Sep 1964	466	11	206	2335	2090	2276	-	2276	-	-	-	-	-
Fountain Creek at Pueblo Period of Record Nov 1963 - Sep 1964	740	16	369	63	63	2332	118	2332	118	1890	496	1890	496
St. Charles at North Period of Record Aug 1952 - Mar 1953	193	5	63	63	63	279	7	279	7	63	63	63	63
Humfries River at Undercliffe Period of Record Feb 1945 - Jan 1946	1605	-	-	-	-	382	14	382	14	114	114	114	114
Arkansas River near Hopeville Period of Record Nov 1963 - Sep 1964	1468	-	-	-	-	134	2	134	2	15	15	15	15
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	1041	32	555	555	555	3231	47	3231	47	1902	1902	1902	1902
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	1356	46	872	872	872	4654	85	4654	85	2744	2744	2744	2744
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	510	16	226	226	226	834	14	834	14	348	348	348	348
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	700	31	337	337	337	3485	105	3485	105	2622	2622	2622	2622
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	957	31	440	440	440	5090	147	5090	147	3070	3070	3070	3070
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	296	7	109	109	109	1040	12	1040	12	547	547	547	547
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	2051	36	1215	1215	1215	3400	122	3400	122	1940	1940	1940	1940
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	3190	53	1940	1940	1940	4460	168	4460	168	2590	2590	2590	2590
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	426	9	185	185	185	636	16	636	16	449	449	449	449
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	1375	-	-	-	-	2454	83	2454	83	1437	1437	1437	1437
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	1687	-	-	-	-	4510	180	4510	180	2590	2590	2590	2590
Arkansas River near Fowler Period of Record Nov 1963 - Sep 1964	1458	-	-	-	-	470	11	470	11	219	219	219	219

Source: Geological Survey, ^{13/}, and Bureau of Reclamation ^{14/}^{1/} Time Weighted Average

	SiO ₂	CaCO ₃	Fe	Cr	Mn	Dissolved Solids	Al	Fe
Leadville Drain at Leadville								
Date of Analysis								
7-1-45						641	7.3	372
9-21-45						536	7.1	291
3-7-46						662	7.1	362
5-17-46						702	7.0	430
California Gulch at Halse								
Date of Analysis								
7-8-45						648	3.3	565
9-21-45						870	4.5	559
3-8-46						784	6.2	556
5-18-46						700	5.9	463

Source: Unpublished data - U. S. Geological Survey

Table V-6

Chemical Quality Municipal Water Supplies
in the Study Area

County	Municipality	Date	pH	Chloride (mg/l)	Sulfate (mg/l)	Total Hardness as CaCO ₃ (mg/l)	Dissolved Solids (mg/l)
Lake	Leadville	6-28-60	7.0	0.0	18.0	48.0	99.0
Chaffee	* Buena Vista	6-29-60	6.9	0.0	4.5	40.0	57.0
	* Salida	6-30-60	7.5	2.6	16.0	153.0	215.0
Fremont	Canon City	9-21-60	7.5	3.9	28.0	95.0	138.0
	Florence	9-21-60	7.8	0.0	15.0	123.0	166.0
Pueblo	Pueblo	5-24-51	7.8	6.0	117.0	162.0	269.0
		9-19-60	7.5	6.4	113.0	186.0	298.0
El Paso	Colo. Springs	4-12-50	7.4	2.5	4.0	19.0	33.0
		5-25-51	8.1	15.0	20.0	154.0	244.0
		9-23-60	6.8	9.5	17.0	60.0	111.0
Huerfano	Walsenburg	5-26-60	7.6	0.0	13.0	97.0	115.0
Otero	* Fowler	7-28-60	7.7	180.0	432.0	304.0	1160.0
	Rocky Ford	9-27-60	7.0	38.0	768.0	808.0	1440.0
	* La Junta	7-28-60	7.4	44.0	875.0	848.0	1660.0
Crowley	* Sugar-City	7-27-60	7.7	46.0	476.0	197.0	1170.0
Bent	* Las Animas	10- 4-60	7.0	100.0	1520.0	1160.0	2850.0
Las Animas	Trinidad	6- 6-51	7.9	1.2	6.7	76.0	98.0
		5-10-60	7.2	0.1	9.8	117.0	140.0

*Entire supply from ground water.

Source: Geological Survey 16/

The quality of the Arkansas River water for irrigation purposes ranges from excellent in the upper reaches to suitable at the Colorado - Kansas State line.^{12/} Most of the areas now under irrigation in the study area have been irrigated for approximately 70 years with about the same quality of water. Some lands have gone out of production due to inadequate drainage and poor quality of water; however, most of the soil now being irrigated has adequate permeability and subsurface drainage to permit leaching when leaching water is available. All major crops grown in the Arkansas Valley are salt tolerant.^{12/}

VI. THE ECONOMY

An economic evaluation was made of the 13-county upper Arkansas study area. The resulting projections of population and industrial growth serve as a basis for estimating future water use requirements and subsequent waste discharges.

Present

Economic Geography

The study area is located in southeastern Colorado and extends from the headwaters of the Arkansas River in the Rocky Mountains to John Martin Reservoir (see figure III-1). In the western portion of the study area mountains rise to elevations of more than 10,000 feet. In the foothills of the mountains are located the metropolitan areas of Pueblo and Colorado Springs. Between the Pueblo-Colorado Springs area and John Martin Reservoir is a rather flat river valley area oriented toward agriculture and irrigation. The different types of geography are the basis for the selection of subarea described in Chapter IV and shown in figure III-1. The study area had a 1960 population of 367,000. As shown in table VI-1 about three-fourths of the people in the study area resided in urban areas. Pueblo and Colorado Springs are the largest cities in the study area. El Paso and Pueblo Counties form the Pueblo-Colorado Springs standard metropolitan statistical area. In addition to Colorado Springs and Pueblo, other urban population centers include Security, Salida, Canon City, Florence, Leadville, Las Animas, Walsenburg, Trinidad, La Junta, and Rocky Ford. Security, Trinidad, Canon City, La Junta, and Walsenburg are the largest of these urban centers. As shown in table VI-1, total study area population increased from 248,000 in 1930 to 367,000 in 1960. Most of this increase occurred between 1950 and 1960. Total population in Area I was about stable and Area III experienced a 10,000 loss. The increase of about 100,000 people in Area II which includes the Pueblo and Colorado Springs metropolitan areas, more than made up for the loss in Area III. In 1964, population of the study area was estimated at 416,000.¹⁷ Again most of this increase occurred in Area II with small gains shown in Area I and very little change in Area III.

Resources Within the Area

The study area is served by four major airlines, six railroad lines, one interstate highway, four U. S. highways, as well as numerous state and local highways.

As shown in table VI-1 about 100,000 of the 367,000 people that live in the area in 1960 resided in rural areas. Much of the farm income was related to crop and livestock production in irrigated areas.

Table VI-1

Study Area Population

	1930		1940		1950		1960	
	Pop.	%	Pop.	%	Pop.	%	Pop.	%
Area I								
Urban	20,277	35.4	24,920	39.6	23,348	48.2	25,433	51.8
Rural	37,023	64.6	37,907	60.4	25,082	51.8	23,651	48.2
Total	57,300	100.0	62,827	100.0	48,430	100.0	49,084	100.0
Area II								
Urban	83,333	72.1	88,951	72.4	127,760	77.6	212,573	80.1
Rural	32,275	27.9	22,944	27.6	36,951	22.4	49,876	19.9
Total	115,608	100.0	122,895	100.0	164,711	100.0	262,449	100.0
Area III								
Urban	24,868	33.0	26,989	38.0	27,226	41.8	27,048	48.7
Rural	50,598	67.0	44,002	62.0	37,948	58.2	28,460	51.3
Total	75,466	100.0	70,991	100.0	65,174	100.0	55,508	100.0
Total Study Area								
Urban	128,478	51.7	140,860	54.9	178,334	64.1	265,054	72.2
Rural	119,896	48.3	115,853	45.1	99,981	35.9	101,987	27.8
Total	248,374	100.0	256,713	100.0	278,315	100.0	367,041	100.0

Source: Bureau of Census ^{18/}

In 1964, more than 75 percent of the total value of farm products sold was from the sale of livestock and livestock products.^{19/} The most concentrated livestock producing area is in the La Junta - Rocky Ford area of Otero County where commercial cattle feeding is practiced on a fairly large scale. As shown in table VI-2, farm products sold in 1964 amounted to nearly \$60 million. This was a reduction in both livestock and crop sales from the 1959 value. Commercial vegetables, wheat, grain sorghums, and sugar beets account for most of the value of crops sold.

The total number of acres irrigated with ground and surface water in the Arkansas valley above John Martin has varied between 241,398 acres in 1954 up to nearly 397,000 in 1959 (See table VI-2). The main crops irrigated included alfalfa hay, grain sorghums, corn, wheat, sugar beets, and vegetables. Most of the irrigation water is obtained either from the Arkansas River or from the alluvium of the Arkansas River, therefore, the number of acres irrigated is related to and varies with the quantity of water which flows down the Arkansas during irrigation season.

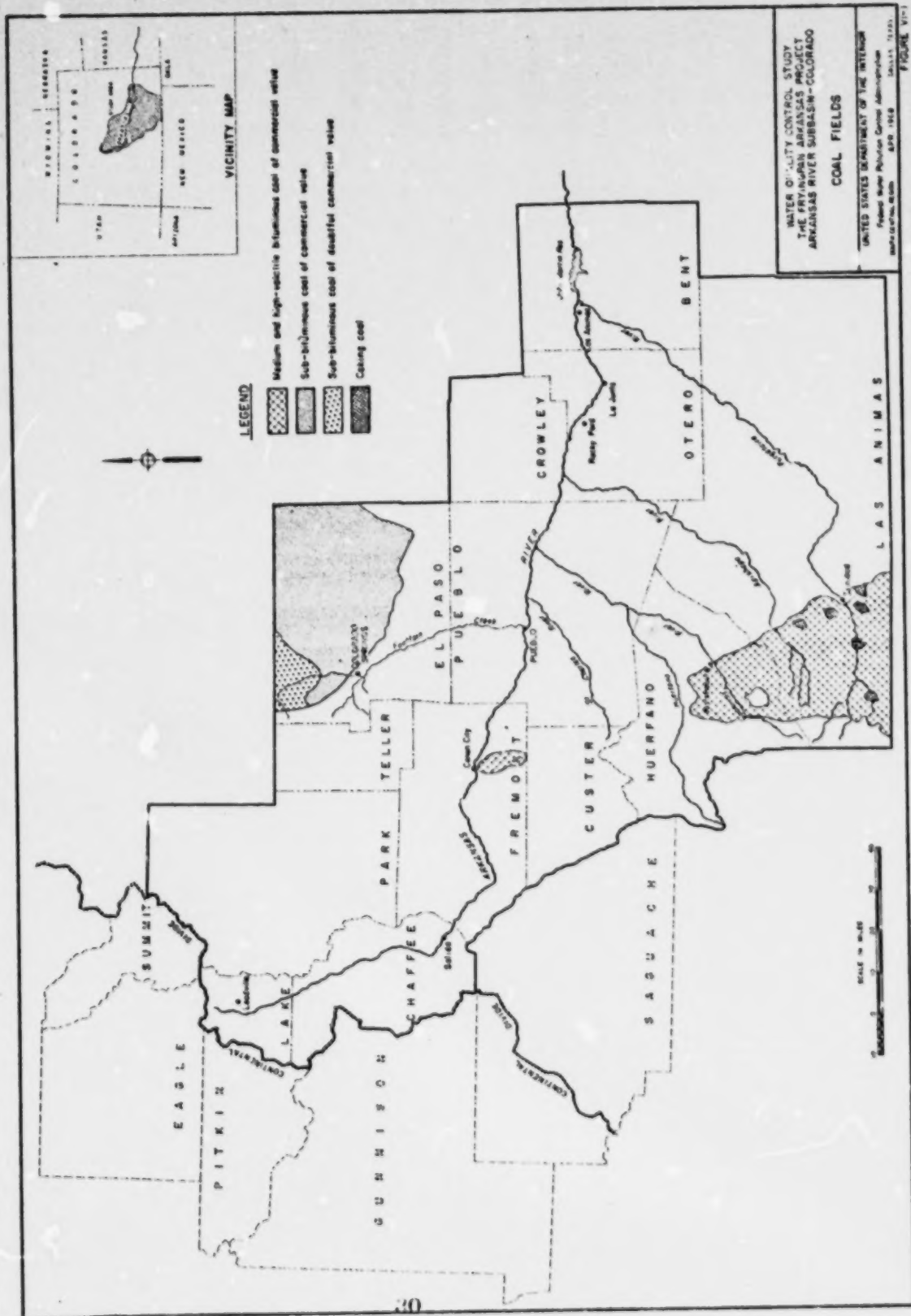
Table VI-2
Agricultural Statistics for the Study Area
 1944 - 1964

	<u>1944</u>	<u>1949</u>	<u>1954</u>	<u>1959</u>	<u>1964</u>
Number of Farms	8,210	7,456	6,601	5,278	4,669
Acres of Cropland Harvested	656,036	692,948	441,786	487,786	345,957
Value of all Crops Sold*	13,257	15,780	8,637	15,102	12,638
Value of all Livestock and Livestock Products Sold*	25,861	35,600	30,442	52,588	39,203
Total Value of All Farm Products*	39,118	51,380	59,079	67,690	61,841
Acres Irrigated	374,790	396,970	241,398	356,654	290,942

* All values in 1,000's of 1960 dollars

Source: Bureau of the Census 19/

The Arkansas River basin has been famous for mining activities since the mid-1800's. Mining communities such as Cripple Creek, Fairplay and Leadville became famous for gold, lead, and silver mining before 1900. In recent years, the mining of gold, lead, and silver has practically ceased due to the high cost of extraction and processing of these metals. Molybdenum an important metal used in the manufacturing of steel is produced in the headwaters of the Arkansas River in Lake County. More than 75 percent of the Nation's molybdenum supply is produced in this area.^{17/} Beryllium, a glamour metal used in rocket construction, is found in Teller County, west of Lake George. Uranium, vanadium, and thorium are just a few of the other new names in Colorado mining today. About one-fourth of the State of Colorado is underlain by coal. In fact, the State ranks first in bituminous coal reserves. Much of this tremendous supply lies in the Arkansas valleys of Las Animas, Huerfano, Pueblo, and El Paso Counties. Although used mostly for industrial fuel, coke and electrical power generation, coal is showing new signs of activity. Research by various mining universities, laboratories, and government agencies has developed new uses for coal and such important by-products as chemical tars, naphthaline, benzoin, and sulfates. The location of coal fields is shown in figure VI-1.



Manufacturing

More than 20,000 people or about 17 percent of the total labor force in 1960 were employed in manufacturing, as shown in table VI-3. The most significant employers are primary metals, fabricated metals, and food and kindred products. These three industries account for more than 75 percent of the total manufacturing employment. Most of the employment in the primary and fabricated metals industry is by the Colorado Fuel and Iron Corporation in Pueblo. Colorado Fuel and Iron obtains its coking coal from its own mines within the Arkansas valley, (see figure VI-1). It also obtains all of its limestone in the same area. Iron ore is brought in from outside the Arkansas valley largely from Wyoming and southwestern Utah.

The main products produced by Colorado Fuel and Iron include wire and wire products, structural and rolled products, tabular goods and pipe, rails and accessories, and chemical products.^{20/} The markets for these products are generally regional, however, some products find national distribution.

Food and kindred products processing is one of the leading industries in the Arkansas valley, employing more than 2,500 people in 1960.^{21/} The main food processing which occurs includes meatpacking, canning, sugar beet processing, and the processing of dairy products. Much of the meat processing is a result of decentralization of market facilities to areas where feed cattle are raised. This has been caused by increased cattle feeding, improved refrigeration, faster transportation, and the fact that it is more economical to transport live cattle once to a feedlot than to continually haul feed to cattle in some feeding area. The main cattle feeds used in this are alfalfa, corn grain sorghums and sugar beet pulp; all of which are very plentiful. The Arkansas valley is very well adapted to the growing of commercial vegetables. This ready source of supply is the reason for the location of five major canning plants in the area. In the last 12 years, the number of canning plants has decreased from five to two, however, the output of the two canneries located in the Arkansas valley today is greater than that of all five previously. The main crops canned include tomatoes, pickles, peas, and snap beans. Most of the input for this industry comes from the immediate areas surrounding the canning factories. However, northern Colorado and Texas are also major sources of input.

In 1959 over 15,000 acres of sugar beet were irrigated in the study area. These sugar beets plus some beets brought in from surrounding areas are processed at the Rocky Ford Sugar Plant.

Most of the dairy manufacturing is centered around the urban areas and is processing of milk and milk products for the large urban populations.

Table VI-3

Study Area Labor Force and Population
1950 and 1960

	1950		1960	
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>
Agriculture, Forestry and Fisheries	10,914	11.3	6,753	5.6
Mining	3,576	3.7	3,243	2.7
Manufacturing	13,466	14.0	20,262	16.8
Primary Metals	7,337	7.6	8,116	6.8
Fabricated Metals	1,041	1.1	5,859	4.9
Food & Kindred Products	1,772	1.8	2,554	2.1
Other Manufacturing	3,266	3.5	3,733	3.0
All Other Employment	63,481	65.9	83,586	69.5
Unemployed	4,893	5.1	6,444	5.4
Total Labor Force	96,330	100.0	120,288	100.0
Total Population	278,315		367,019	
Labor Force % of Population		34.6		32.8

Source: Bureau of Census^{21/}

The largest single source of employment in the Arkansas valley is military activities. In 1964, there were an estimated 26,500 military personnel in the area.^{22/} Civilian employment in 1964 was estimated at 9,000. Most of these government employees are located at four major military facilities in El Paso and Pueblo Counties. They include Fort Carson, south of Colorado Springs, North American Air Defense Command (NORAD) headquarters at Ent Air Force Base in Colorado Springs, the Air Force Academy, north of Colorado Springs, and the Pueblo Army Depot, east of Pueblo. An estimated \$50 million annually is added to the economy of the Colorado Springs area by the three military establishments in the Colorado Springs area. In addition to the military, there are five State and Federal institutions located in the area which affect the economy considerably. These institutions are the Colorado State Reformatory, the Colorado State Penitentiary, the Veterans Administration Hospital, the Colorado State Hospital, and Southern Colorado State College. These five institutions employed about 4,000 people in 1965.

The Colorado Springs area is generally oriented to tourism and has been for 75 years. Some of the attractions for tourist include

the Royal Gorge at Canon City, Pikes Peak near Colorado Springs, Cheyenne Mountain Zoo in Colorado Springs, Seven Falls near Colorado Springs, Cave of the Wind at Manitou Springs, Santa's Workshop at Cascade, the Rocky Mountain Kennel Club at Colorado Springs, the Air Force Academy north of Colorado Springs, and the Colorado Springs Fine Arts Center. These tourist attractions average about 4 million visitor days per year.^{23/}

The Arkansas River valley has long been known as one of the best hunting and fishing areas of the United States. The Arkansas River is known for its productivity of large brown trout and easy accessibility to the public. Big game hunting is also important in the Arkansas valley. In 1964 there were 360 elk, 7,151 deer, 765 antelope, 85 bear, 192 turkeys, and 22 bighorn sheep killed.^{23/}

The Future

Economic projections are necessary as a basis for estimating future municipal, industrial, and water quality control needs of the area. The recently completed regional study of the Arkansas-Red River systems was relied on as a major source of information for this study.^{24/} The projections presented reflect an updating of the Ark-Red study as well as information contained in studies made by the State of Colorado and the Corps of Engineers. One of the most significant factors in the growth of the upper Arkansas area is the increased recreation and tourism anticipated in an economy which has more spare time. Also anticipated to have a marked effect on the growth of the Arkansas valley is the increased food processing necessary to feed an ever expanding population and increased extraction of the glamour metals mined in the area.

Based on past historic growth and an analysis of resources in each of the subareas, population projections were made to assist in determining the needs for water supply and pollution control. Population projections for these subareas for the years 1980, 2000, 2020, and 2070 are shown in table VI-4.

Heavy industrial water users are expected to be the same industries which are presently located in the area. These include iron and steel production, and food and kindred products processing. Increases in food and kindred product output are anticipated to be mainly in the processing of sugar beets and meat. Iron and steel production is anticipated to be in the order of 2.5 million tons annually by the year 2020. This value was developed in the 1964 Public Health Service study.^{24/} Food and kindred product processing is expected to triple by the year 2020.

Table VI-4

Population Projections for the Study Area
1960, 1980, 2000, 2020, and 2070
 (1,000's)

	<u>1960</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>	<u>2070</u>
Area I					
Urban	25	40	56	73	123
Rural	24	20	18	17	17
Total	49	60	74	90	140
Area II					
Urban	212	404	678	1,061	2,367
Rural	50	35	25	20	15
Total	262	439	703	1,081	2,382
Area III					
Urban	27	35	42	49	63
Rural	28	19	18	17	15
Total	55	54	60	66	78
Total Study Area					
Urban	264	479	776	1,183	2,553
Rural	102	74	61	54	47
Total	366	553	837	1,237	2,600

VII. WATER QUALITY CONTROL

General

Water quality studies are a necessary part of effective water resources management. Frequently it is found that the regulation of streamflow can make a substantial contribution to the protection, preservation, or enhancement of the quality of water for established or potential beneficial uses.

Congress emphasized the importance of water quality control as it applied to our Nation's water resources by the enactment of the Federal Water Pollution Control Act, Public Law 84-660, as amended by Public Law 87-88. Under the provisions of this Act, consideration must be given to the inclusion of storage for regulation of streamflow to control water quality in any reservoir being planned by a Federal agency. However, the Act stipulates that storage for the regulation of streamflow for water quality control purposes should not be provided as a substitute for adequate treatment of wastes at the source.

In determining the amount of water from storage required to preserve the quality of a stream, it is necessary to make allowances for natural flows that could be expected to occur in the stream in the absence of the proposed project. The flows that can be expected to occur in area streams in the absence of the proposed project are shown in Appendix A, figures A-1 and A-2. Figure A-3 compares the flows now occurring in the main stem of the river with those anticipated after completion of the Fryingpan-Arkansas Project.

Quality Criteria

After consideration of the present and potential pollutants in the area and possible measures for control, it was concluded that dissolved oxygen and dissolved solids were most appropriate to use as a basis for evaluation of the possible use of flow regulation for control of the quality of surface waters in the study area.

Dissolved Oxygen - Anaerobic conditions must be avoided in streams to prevent nuisance conditions and the loss of aesthetic values of streams and contiguous land areas. It is necessary to maintain relatively high dissolved oxygen concentrations if a stream is to be of use for the propagation of fish and other aquatic life, recreation, and municipal and industrial water supply. Maintenance of the following dissolved oxygen concentrations is considered necessary if the designated water uses (see table B-2) are to be preserved.

Main Stem of Arkansas River

From: Source above Leadville	
To: Canon City	6.0 mg/l
From: Canon City	
To: Pueblo	5.0 mg/l
From: Pueblo	
To: John Martin Reservoir	4.0 mg/l

Tributaries above Fountain Creek	6.0 mg/l
----------------------------------	----------

Tributaries below Fountain Creek (minimum concentration in headwater areas is 6.0 mg/l)	3.0 mg/l
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Fountain Creek

From: Source	
To: Confluence with Monument Creek	6.0 mg/l
From: Confluence with Monument Creek	
To: Confluence with Arkansas River	4.0 mg/l

Dissolved Oxygen (D.O.) concentrations listed above are consistent with state Water Quality Standards (see Appendix B) with two exceptions; state standards do not include a minimum concentration for Fountain Creek below its confluence with Monument Creek and the minimum concentration in the Arkansas River below Pueblo is set at 3.0 mg/l except for a small reach near Rocky Ford that is set at 4.0 mg/l. Expected changes in stream use will make increased dissolved oxygen concentrations desirable. Study area growth projected to the year 2070 will most likely involve urbanization of much of the area surrounding Fountain Creek. Also increasing waste discharges and reduction of irrigation due to urbanization of farm lands are expected to produce perennial streamflow. These factors probably will result in the development of recreational areas along the creek making aesthetics the primary beneficial use of the stream. Use of the Arkansas River below Pueblo is expected to be limited primarily to irrigation with minor industrial use throughout the study period. However, plans for channel improvement by the Department of the Army, Corps of Engineers, include development of eighteen river bed areas, that would be cut off by channel straightening, for recreation and fish and wildlife enhancement. Prevention of nuisance conditions and preservation of the aesthetics of the river will become more important when the recreational areas are established.

It was recognized that lower minimum dissolved oxygen concentrations could possibly prevent undesirable nuisance and aesthetic

conditions. However, a high percentage of the flow in both streams are expected to be waste water and high biochemical oxygen demand concentrations probably will exist simultaneously with minimum dissolved oxygen concentrations in the flowing stream. If a substantial oxygen reserve is not maintained in the stream, anaerobic conditions could develop very rapidly in pools and diversion ditches or in any stream reach where the velocity of flow is reduced. It was therefore concluded that a dissolved oxygen concentration of at least 4.0 mg/l should be maintained in both Fountain Creek and the Arkansas River below Pueblo.

Total Dissolved Solids - Limitations on dissolved solids concentrations in drinking water are primarily based upon the palatability and the physiological effects of high solids on some people. The Public Health Service Drinking Water Standards-1962¹¹ recommended that the total dissolved solids concentration in a water supply not exceed 500 mg/l except where, in the judgment of the reporting agency and the certifying authority, no other suitable supplies are or can be made available. No limitations have yet been established on the quantity of dissolved solids an individual can safely consume. Many communities in the United States and in foreign countries use water having a concentration of dissolved solids in excess of 500 mg/l.

Restrictions on dissolved solids for uses other than drinking water are highly variable. Generally, however, supplies with concentrations above 1,000 mg/l are undesirable for most uses. Restrictions on dissolved solids concentrations included in state Water Quality Standards are described in Appendix B.

Quality Problems

Inorganic Pollutants -

Surface water quality in the study area is degraded by heavy metals and acids emanating from abandoned mining operations in the vicinity of Leadville, Colorado; acids released from exposed mineral deposits at the head of the South Fork of Lake Creek; and irrigation return flows.

Below Pueblo irrigation return flows frequently raise dissolved solids concentrations above 2,000 mg/l. This pollution has persisted for many years such that surface waters below Pueblo are now used principally for irrigation of salt tolerant crops; other uses are very limited.

It is not expected that the Fryingpan Arkansas Project will cause any noticeable increase in mineral concentrations of surface waters. The project will provide additional water for irrigation and,

therefore, the quantity of return flow will be increased, however, use of the available water in the irrigation process is expected to be very similar to current applications, resulting in practically the same return flow quality.

Organic Pollutants -

Organic pollutants are discharged to surface water courses by municipalities and industries throughout the river basin. However, municipal and industrial water use and waste production is largely centered in the areas of Pueblo, Colorado Springs, Canon City, La Junta, and Trinidad. Smaller but substantial quantities of water use and waste production occur in the vicinities of Leadville, Salida, Walsenburg, Rocky Ford, and Las Animas. At the present time, municipal waste discharges to study area streams are estimated to be between 40 and 50 mgd with a population equivalent (PE) of about 60,000. Biochemical oxygen demand (BOD) removal from wastes is estimated to be from 60 to 90 percent. However, the majority of the waste treatment plant provide secondary treatment with BOD removal approaching 90 percent. Principal sources of industrial water use and waste discharges are the iron and steel, food and kindred, and mining industries. If waste production is reached as projected, by the year 2020, the natural unregulated streamflow cannot assimilate organic pollutants discharged to the streams, in certain areas, without reducing the dissolved oxygen content below minimum desirable levels.

Streamflow required to assimilate anticipated waste loads, following adequate treatment, are summarized in table VII-1. For the smaller communities the anticipated streamflows will be sufficient to assimilate the remaining organic materials without reducing the dissolved oxygen content below the previously established water quality criteria. At Colorado Springs in Fountain Creek and in the Arkansas River, however, additional flow or advanced waste treatment will be necessary if the criteria is to be met. Supplemental flow requirements estimated for 2020 and 2070 at three levels of treatment efficiency are presented in table VII-2.

Quality Control

Inorganic Pollutants Control -

Efforts have been made to determine the extent of pollution from heavy metals and acid emissions in the upper basin. More detailed studies will be necessary before control methods are developed. However, present information indicates that application of control measures at the source will be more effective than control of waste concentrations in the stream system by flow regulation.

Table VII-1

Streamflow Required for Quality Control ^{1-4/}

<u>Point of Control</u>	<u>Year</u>	<u>Estimated Minimum Streamflow in cfs Needed to Assimilate Projected Future Waste Discharges</u>						
		<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>October</u>
Leadville	2070	-	0.4	1.6	2.8	2.8	1.6	0.4
Buena Vista	2070	-	0.1	0.6	1.0	1.0	0.6	0.1
Salida	2070	-	0.5	1.9	3.4	3.4	1.9	0.5
Canon City	2070	-	0.9	3.7	6.5	6.5	3.7	0.9
Pueblo	2020	-	18.6	100.4	186.1	186.1	100.4	18.1
	2070	-	38.7	208.9	386.8	386.8	208.9	38.7
Colorado Springs	2020	26.9	50.4	140.9	251.9	251.9	140.9	50.4
	2070	61.9	116.0	324.9	580.2	580.2	324.9	116.0
Walsenburg	2070	0	0.4	2.5	3.6	3.6	2.5	0.4
Fowler	2070	0.1	0.2	0.4	0.6	0.6	0.4	0.2
Rocky Ford	2070	4.5	6.0	13.5	19.5	19.5	13.5	6.0
La Junta	2070	1.0	1.3	2.9	4.2	4.2	2.9	1.3
Las Animas	2070	0.7	0.9	2.0	2.8	2.8	2.0	0.9
Trinidad	2070	0.8	1.1	2.4	3.4	3.4	2.4	1.1

^{1/}Streamflow required to prevent depression of dissolved oxygen levels below desirable minimums.

^{2/}Waste treatment to provide 90 percent BOD removal was assumed in computations.

^{3/}Because of the prevailing low stream temperatures during the winter and early spring months and high reoxygenation rates, streamflow needs are expected to be negligible during some months. Needs are negligible during months omitted from the table.

^{4/}Supplemental streamflow requirements are presented in table VII-2.

Table VII-2

Projected Supplemental Streamflow
Required for Water Quality Control

		Supplemental Annual Flow Needed ^{1/} (1,000 ac.-ft. per year)					
		Year 2020			Year 2070		
% BOD Removed from Wastes		90	93	99	90	93	99
<u>Point of Control</u>	<u>Stream</u>						
Colorado Springs ^{2/}	Fountain Creek	55.1	21.9	0	126.9	50.4	0
Pueblo ^{3/}	Arkansas River	0	-	-	85.2	20.8	0
Rocky Ford	Arkansas River	0	-	-	0.6	-	-
La Junta	Arkansas River	0	-	-	0.2	-	-
Las Animas	Arkansas River	0	-	-	0.1	-	-

^{1/} Supplemental annual flows were projected through a comparison of the total streamflow required to assimilate anticipated waste loads with the streamflow expected during a low flow period having a recurrence interval of once in 20 years.

^{2/} Dry stream conditions were assumed.

^{3/} Computation based on the assumption that Pueblo Reservoir was completed and that direct releases to the river below the reservoir will gradually be reduced to zero from 1990 to 2040 due to increase in appropriations in and above the reservoir for water supplies.

It does not appear that a reduction of mineral levels in the Arkansas River below Pueblo is necessary to maintain the irrigation and industrial use (see table B-2) established by State Water Quality Standards. To develop other uses, such as municipal and industrial process supplies, would require major reductions. However, with current irrigation practices, adequate supplemental flows for affecting this reduction could not be provided from present and anticipated water resources. The entire flow of the river below Pueblo is used several times in the irrigation process resulting in high mineralization of the water. Practically all water from tributaries below Pueblo have a high mineral content making it unsuitable for dilution of main stem resources. It would be necessary to import water for mineral quality regulation from another basin and this would not be practicable. If water is imported it would be more effective to satisfy municipal and industrial demands below Pueblo directly with import water.

Dissolved solids concentrations in Arkansas River waters now increase from approximately 300 mg/l at Pueblo to approximately 2,000 mg/l at the Colorado-Kansas state line indicating that available water is used about four times in Colorado below Pueblo. If available water was used only one time in the irrigation process, in this area. The dissolved solids concentration would possibly be increased to only about 600 mg/l. Unfortunately, though water supplies are not adequate to satisfy all existing water rights without multiple uses. Reduction of water losses by improving irrigation practices and conveyance facilities could lower the diversion ratio (quantity water diverted from stream per acre irrigated) but would probably not result in a reduction in the number of times the available water is used in the irrigation process. Under current law (appropriation doctrine) a reduction in water use by senior water rights holders would most likely result in an increased use by junior water rights holders. It appears that limitation of the quantity of land used for irrigation possibly through land use zoning as well as conservation measures to lower the diversion ratio or additional water imports will be required if multiple cycling of available supplies through the irrigation process are to be avoided or reduced for improvement of stream quality.

Organic Pollutants Control -

Studies indicate that control of organic pollutants by supplementing streamflow would be desirable in only two study area streams, the Arkansas River below Pueblo and Fountain Creek below Colorado Springs (see table VII-2). In all other streams, expected natural or project flow will be adequate to assimilate properly treated (90 percent biochemical oxygen demand removal) organic wastes.

Several methods were considered for controlling the quality in the two streams. Simplified cost analyses (see Appendix C) were made

to compare the cost of providing storage for supplementing streamflow with the cost of other control methods. In addition to the methods analyzed in Appendix C, systems for stream aeration were examined. However, stream aeration was found to be impractical where dissolved oxygen levels above about 2.0 mg/l are to be maintained.

It is anticipated that future utilization of the limited water resources provided by the Fryingpan-Arkansas Project for municipal and industrial supplies would make a greater contribution to the economy of the nation than their use for quality control. Therefore, in the cost analyses, it was assumed that storage to be used for supplementing streamflow for adjusting dissolved oxygen concentrations could be provided at seven potential damsites on tributaries below Pueblo (see table VII-3 and figure VII-1).

Water stored in these reservoirs would be highly mineralized and would provide very little if any reduction of mineral concentration where released to the main stem for regulation of dissolved oxygen concentrations. It was recognized that it may be necessary to purchase water rights from irrigators if storage is provided. However, water released for quality control could be sold to downstream irrigators after it is mixed with flow in the stream where quality control is required. It was assumed that water sales would pay for the purchase of water rights, therefore, only the cost of structural facilities were included in cost comparisons.

The cost analyses (Appendix C) are interesting in that they indicate that maximum use of flow regulation by construction of reservoirs, and release of stored waters would possibly provide the most economical method for water quality control in both Fountain Creek and the Arkansas River below Pueblo.

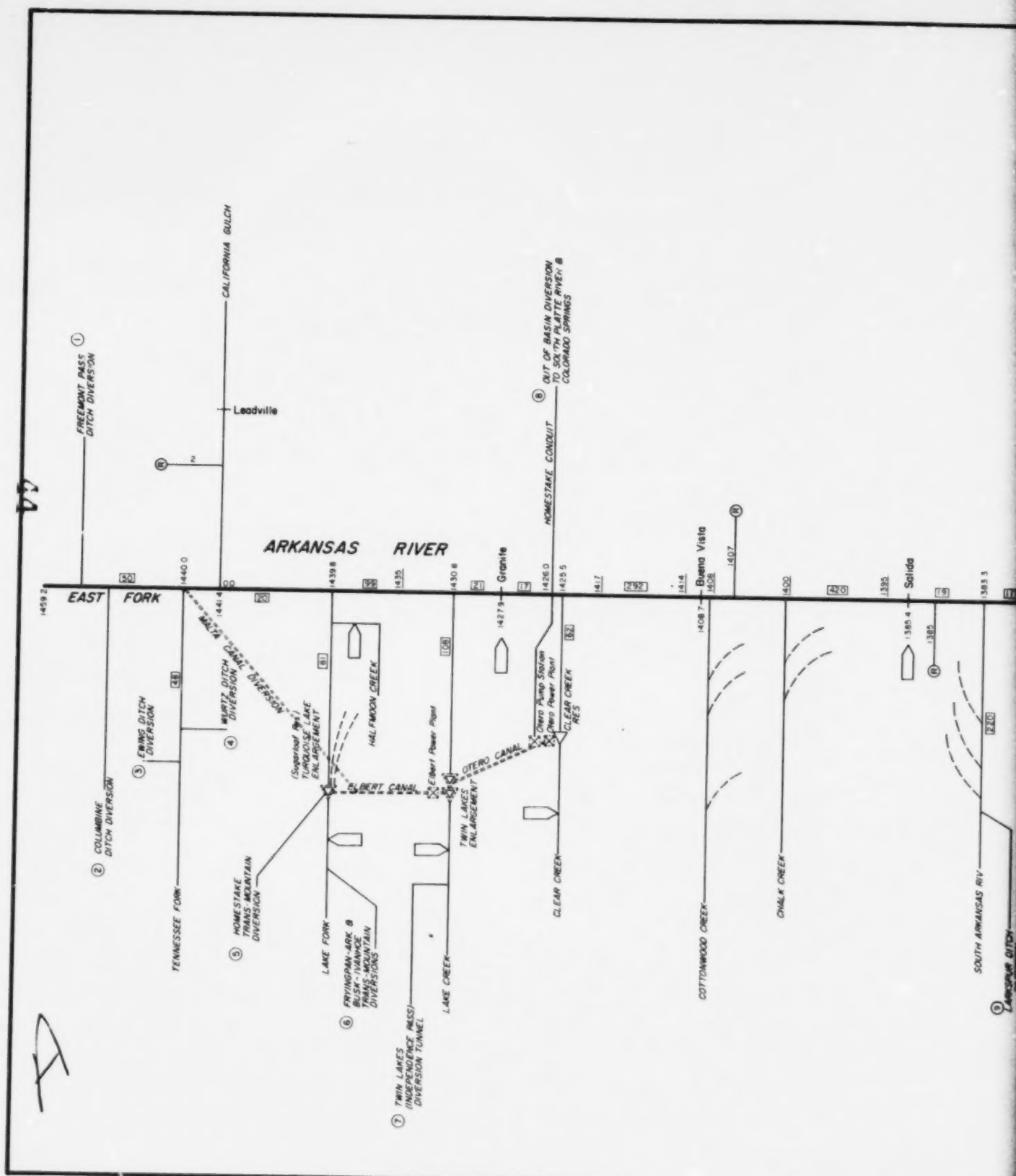
Table VII-3

Potential Damsites
Locations and Estimated Reservoir Yields^{1/}

<u>Site</u>	<u>Location</u>	<u>Average Annual Yield</u>	
		<u>(ac.-ft.)</u>	<u>(mgd)</u>
Ute Pass Damsite	Fountain River above Manitou Springs, Colorado	30,000	26.9
Fountain Creek Damsite	Fountain Creek near Pinon, Colorado	15,800	14.1
Pleasant View Damsite	St. Charles River near Pueblo, Colorado	14,100	12.6
Welton Damsite	Huerfano River about 5 miles above mouth	14,000	12.5
Apishapa Damsite	Apishapa River about 6 miles above mouth	24,000	21.5
Timpas Damsite	Timpas Creek about 10 miles above mouth	20,000	17.9
Adobe Damsite	Adobe Creek about 5 miles above mouth with diversion from Horse Creek into Adobe Creek	20,000	17.9
Purgatoire Damsite	Purgatoire River about 18 miles above mouth	<u>20,100</u>	<u>18.0</u>
Total		158,000	141.4

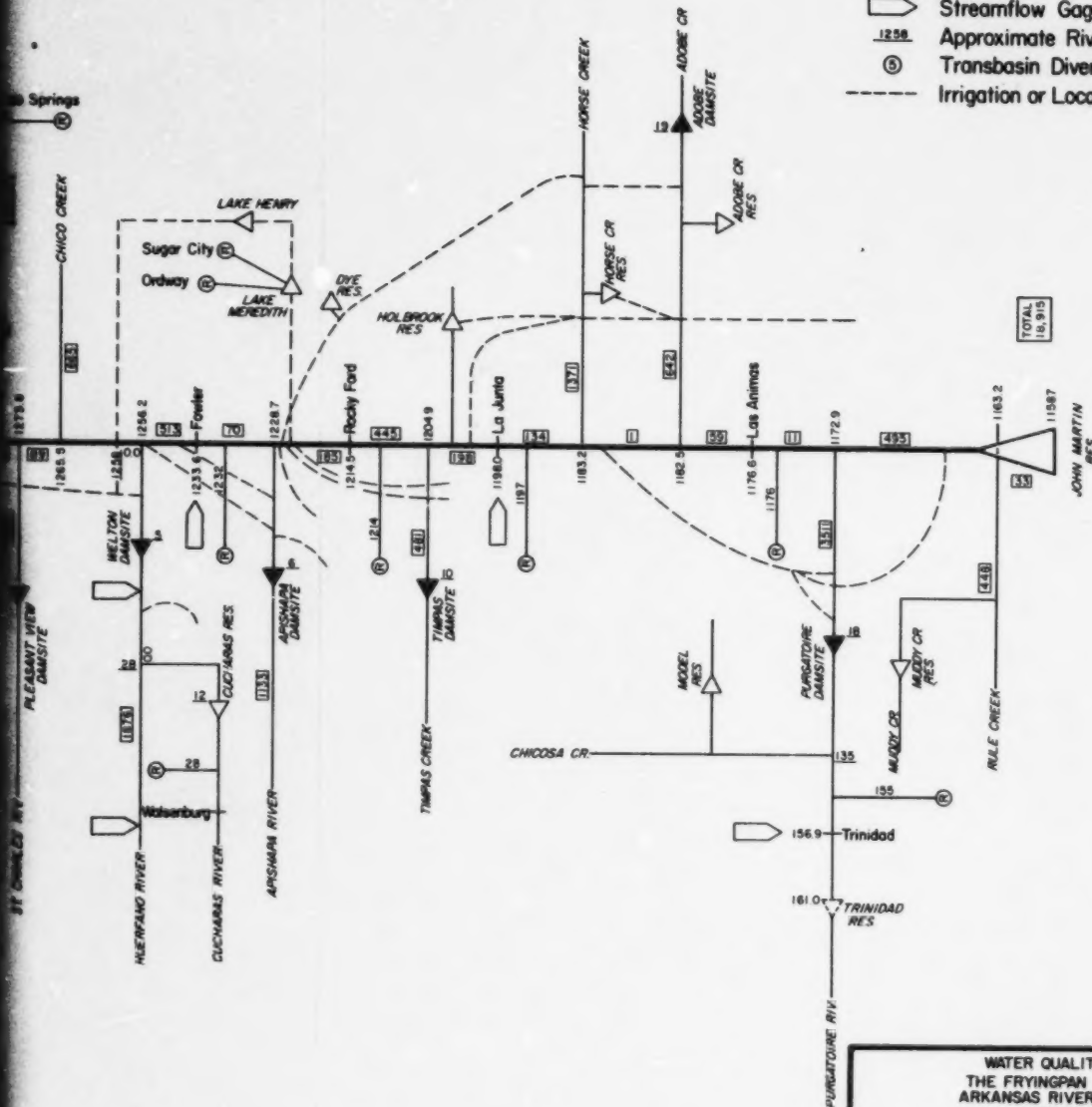
^{1/} Estimated yields are a function of the recorded flows and do not take water rights into consideration.

Source: Corps of Engineers



LEGEND

- ▽ Existing Damsite
- ▼ Potential Damsite
- === ▽ Authorized or Planned Projects
- 1172 R Return Flow & Approximate River Mile
- 1375.0 + River Miles
- 482 Drainage Area
- Streamflow Gage
- 1258 Approximate River Mile
- ⊙ Transbasin Diversions
- - - Irrigation or Local Diversion Canals



NO SCALE

WATER QUALITY CONTROL STUDY
THE FRYINGPAN ARKANSAS PROJECT
ARKANSAS RIVER SUBBASIN-COLORADO

RETURN FLOW AND DIVERSION DIAGRAM

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

SOUTH CENTRAL REGION
JUN 1, 1966
DALLAS, TEXAS

FIGURE VII-1

- Organic Pollutants Control in the Arkansas River below Pueblo -

Releases from the Pueblo reservoir for other uses such as irrigation and power generation could provide adequate quality control streamflow in the Arkansas River below Pueblo, through the terminal year (2070) of the study if the proposed project design flows could be maintained. However, it is expected that direct releases to the river below the reservoir will gradually be reduced from the year 1990 to the year 2040 due to increases in use of water resources in and above the reservoir for municipal and industrial water supplies. Authorized and presently developed supplies will probably be adequate through 1990.

At the present time adjudicated water rights for the study area resources far exceed the quantity of water normally available and a large portion of the available water resources of the entire basin are appropriated for irrigation. Therefore, further urban development will require additional importation of water from other basins, a re-apportionment of water resources within the basin, or an intensive program for renovation and reuse of waste water.

Prospects for additional water imports are limited. It appears that much of the good quality (low mineral concentration) water available or planned for development in the basin will eventually be first used to satisfy municipal and industrial processing water needs and later reclaimed for other uses, such as irrigation and industrial cooling. Since irrigation return flows in the study area below Pueblo will probably continue to raise mineral concentrations in surface waters above levels desirable for municipal and many industrial uses, most of the good quality water suitable for municipal supplies, will be found in the study area above Pueblo. Quality control computations (see table VII-2) in this study are based on the assumption that by the year 2040, development will progress to the point that the entire flow of the Arkansas River above Pueblo will be first used for municipal and industrial supplies prior to discharge as waste water to the stream system below Pueblo. Consequently, water from the Fryingpan-Arkansas Project will not be available for direct release from the Pueblo Reservoir to the river channel below Pueblo after 2040. It is anticipated that river flow below Pueblo will then be formed by tributary inflow, municipal and industrial waste water, and irrigation return flow.

Other projects to provide storage below the reservoir may then be needed to supplement streamflow. The following method was found to be the least costly of all those considered to preserve the quality of water in the Arkansas River below Pueblo:

<u>Date</u>	<u>Action</u>
1975	Complete Pueblo Reservoir.
2030-2055	Complete the following reservoirs to provide water for supplementing Arkansas River flows at critical times.

<u>Year</u>	<u>Reservoir</u>	<u>Quantity Water Provided (Acre-feet/year)</u>
2030	Pleasant View	14,100
2032	Welton	14,000
2034	Apashapa	24,000
2038	Timpas	20,000
2055	Adobe	12,900

- Organic Pollutants Control in Fountain Creek -

With treatment facilities that remove only 90 percent of the BOD of wastes discharged to the stream, utilization of all water resources potentially available within the Fountain Creek basin for supplementing flows still would not preserve the stream's quality. Advanced waste treatment facilities (facilities that will remove more than 90 percent of the BOD of the wastes) will be needed and storage for flow regulation would be desirable. However, since all the available water resources in the Arkansas River basin above Pueblo could be used for municipal and industrial water supplies, storage in reservoirs included in the Fryingpan-Arkansas Project would not be available for use in controlling water quality by supplementing streamflow in Fountain Creek.

Water resources within the Fountain Creek Basin are very limited, however, cost analyses presented in Appendix C (see table C-1 and C-3) indicate that it would be economically advantageous to provide as much storage as possible for quality control in lieu of additional treatment. The following method was found to be the least costly of all those studied for controlling the quality of water in Fountain Creek.

<u>Date</u>	<u>Action</u>
1970	Complete Ute Pass Reservoir to provide 30,000 acre-feet of water per year for supplementing streamflow. Provide waste treatment facilities capable of 90 percent BOD removal.
1990	Complete Fountain Creek Reservoir to provide 15,800 acre-feet of water per year for supplementing streamflow. Provide waste treatment facilities capable of 90 percent BOD removal.
2010	Start modifying waste treatment facilities to provide 93 percent BOD removal. All facilities (228 mgd capacity) must be modified by 2060.
2060	Construct waste treatment facilities to provide 99 percent BOD removal from all wastes produced in excess of 228 mgd.

Although storage is not provided in Fryingpan-Arkansas Project reservoirs exclusively for water quality control in Fountain Creek it should be noted that it would be possible to route water from the Arkansas River above Pueblo through Fountain Creek by pumping (utilizing Colorado Springs water supply pipeline) to provide supplemental flows for a limited period of time, possibly until the year 2010. At the same time, streamflow in the Arkansas River below Fountain Creek would not be materially altered and could still be used for irrigation. After 2010, it would be necessary to provide other quality controls. It is recognized that extensive policing of any supplemental flow put into Fountain Creek would be required to insure that it was not removed prior to reaching the Arkansas River. This activity must be considered when flow regulation is compared to other methods of water quality control.

Discussion

Although it appears desirable and economically advantageous to provide storage for streamflow regulation to preserve water quality, changes in the water law of Colorado would possibly be required to obtain water rights for implementing a project for this purpose. Adjudicated water rights, primarily for agricultural use, already exceed water resources normally available. While water rights for domestic use can be acquired from irrigators by purchase through condemnation procedures, this method of acquisition is not now possible for purchasing water to be used for streamflow regulation. Under present law, water rights for this purpose would have to be purchased in the same manner as any other property right.

Some measure of flow regulation could possibly be implemented by agreements to allow storage of water appropriated for irrigation at strategic locations in the basin where releases for irrigation would provide a dual benefit. Since supplemental flows for quality control are needed during the irrigation season, releases from storage primarily for irrigation could increase streamflow where it is needed for quality control. As an example, it might be possible to transfer some storage from John Martin Reservoir to Ute Pass, Pleasant View, or Welton sites.

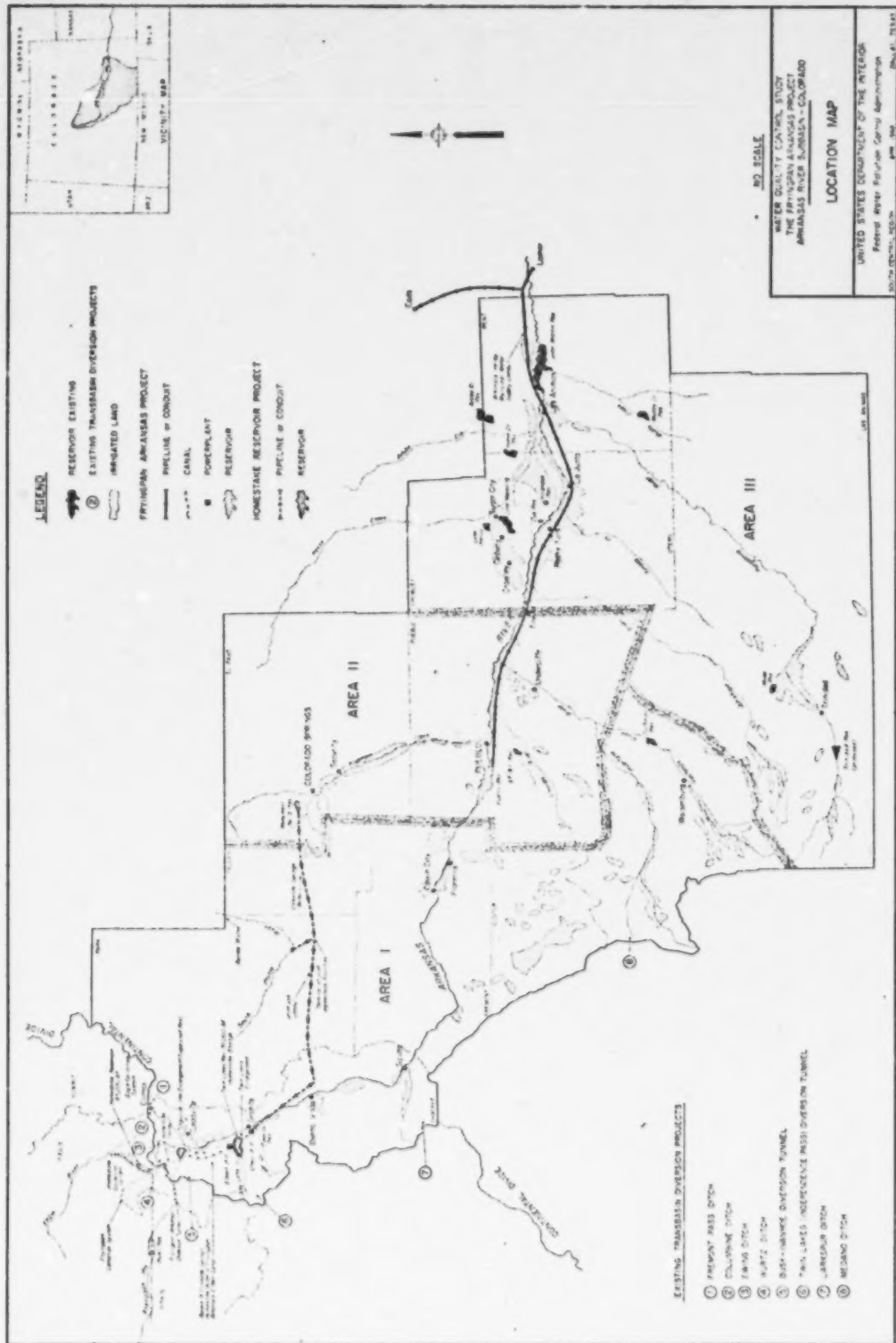
While appropriation of water for storage to be used exclusively for quality control in study area streams is not considered possible due to the scarcity of water resources, it does not appear impossible to develop flow regulating facilities that would provide supplemental flows where required for quality control through dual use of the available resources. Studies should be continued in cooperation with state agencies to develop a comprehensive plan for regulation of flow throughout the basin to gain optimum use of the limited resources available and to develop the legal base necessary for implementation of the plan.

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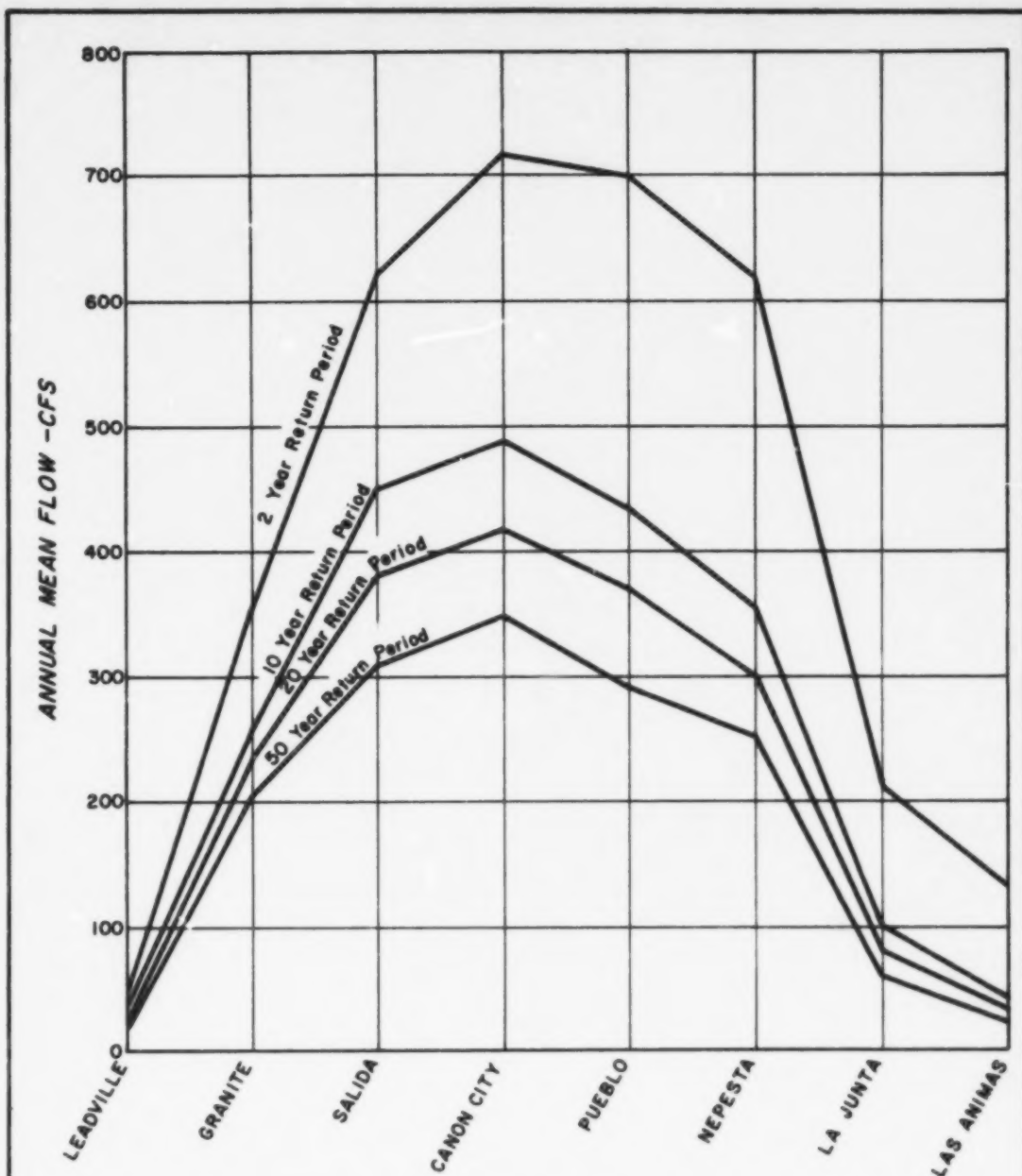
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APPENDIX

A-1

APPENDIX A
· STREAMFLOW ANALYSIS



GAGING STATION	PERIOD OF RECORD
LEADVILLE*	OCT. 1910 - SEP. 1924
GRANITE	APR. 1910 - SEP. 1964
SALIDA	AUG. 1898 - SEP. 1899 APR. 1901 - OCT. 1903 OCT. 1909 - SEP. 1964
CANON CITY	JAN. 1888 - SEP. 1964
PUEBLO	JAN. 1886 - DEC. 1887 SEP. 1894 - SEP. 1964
NEPESTA	OCT. 1913 - SEP. 1964
LA JUNTA	APR. 1912 - SEP. 1964
LAS ANIMAS	MAY 1939 - SEP. 1964

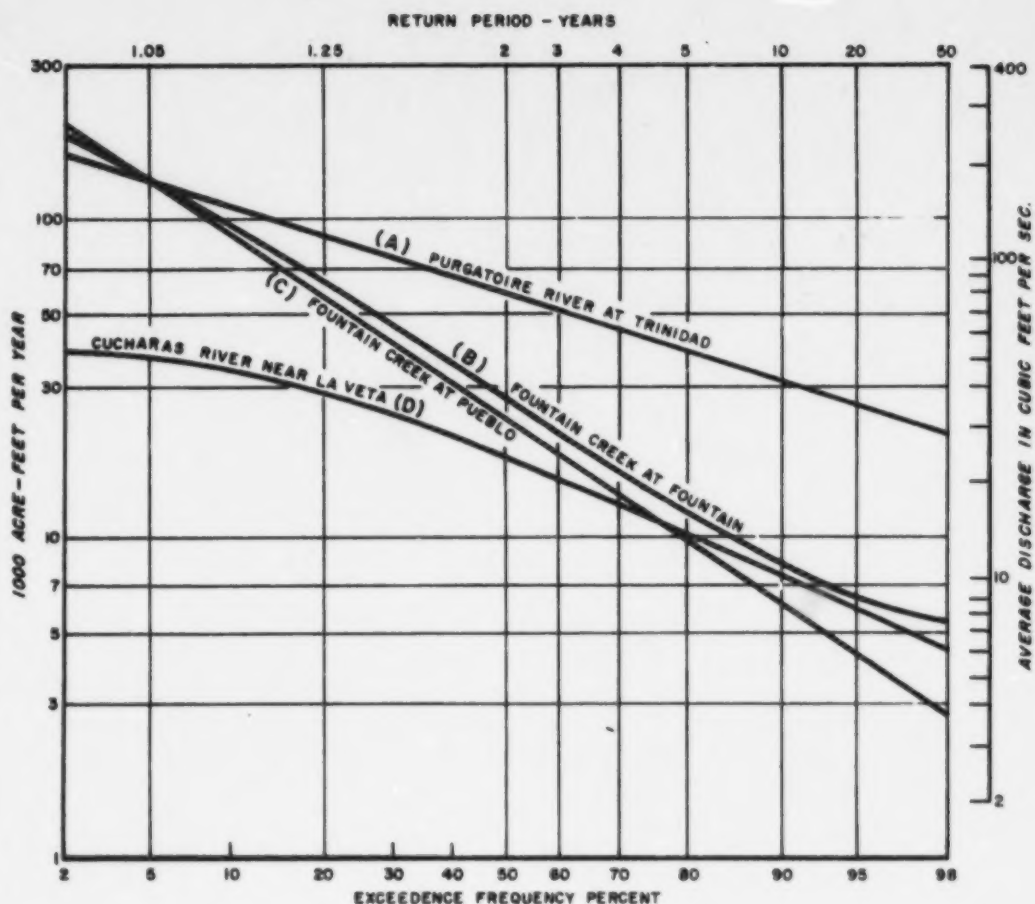
* EAST FORK ARKANSAS

WATER QUALITY CONTROL STUDY
THE FRYINGPAN ARKANSAS PROJECT
ARKANSAS RIVER SUBBASIN-COLORADO

STREAMFLOW ANALYSIS
MAINSTEM ARKANSAS RIVER
(PRE-PROJECT CONDITIONS)

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

SOUTH CENTRAL REGION APR. 1968 DALLAS, TEXAS



PERIOD OF RECORD

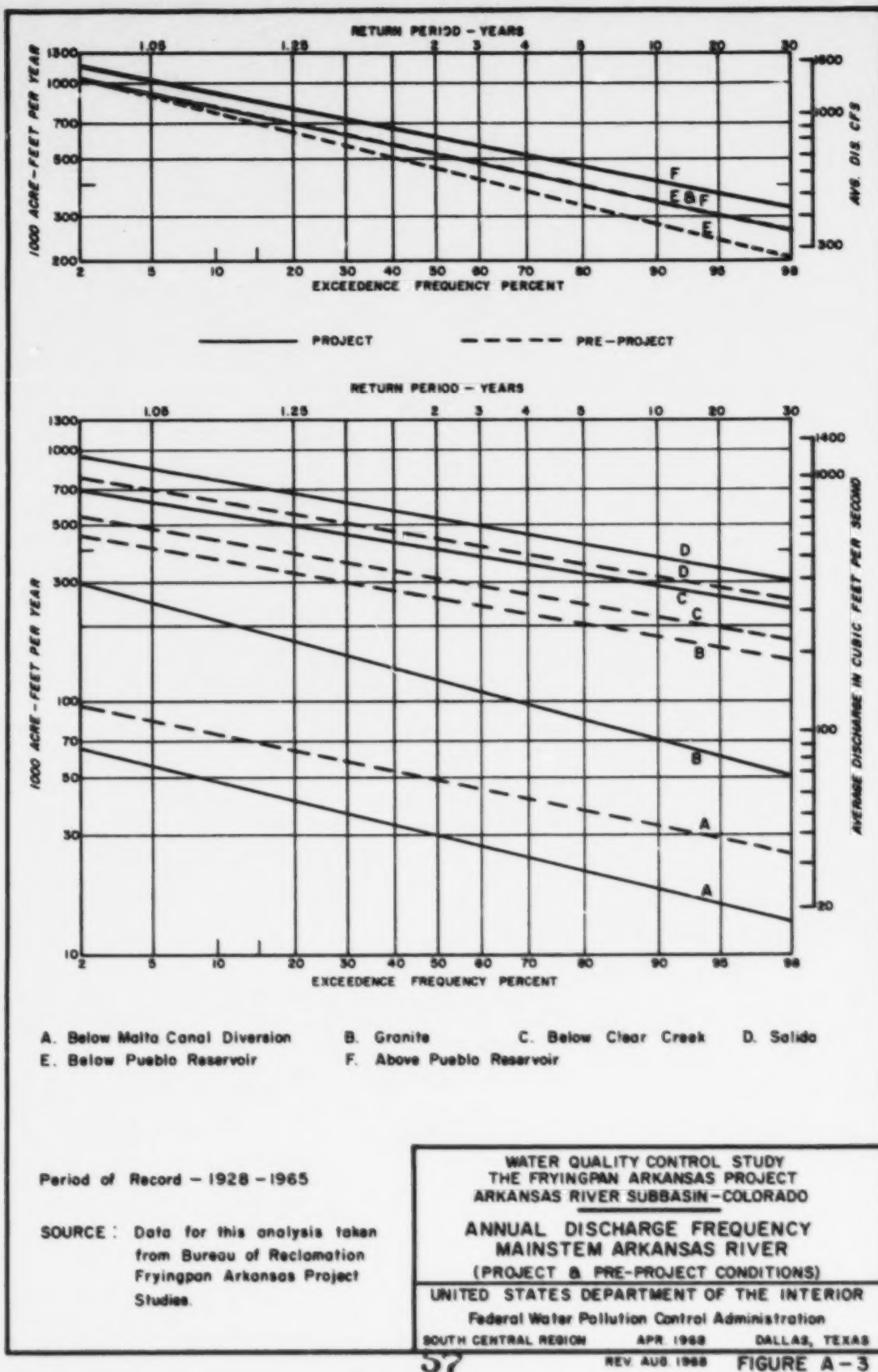
- (A) OCT. 1885 - SEP. 1889
OCT. 1907 - NOV. 1908
SEP. 1909 - NOV. 1912
OCT. 1915 - SEP. 1960
OCT. 1962 - SEP. 1964
- (B) OCT. 1938 - SEP. 1954
- (C) JAN. 1922 - SEP. 1925
OCT. 1940 - SEP. 1964
- (D) OCT. 1934 - SEP. 1964

WATER QUALITY CONTROL STUDY
THE FRYINGPAN ARKANSAS PROJECT
ARKANSAS RIVER SUBBASIN-COLORADO

ANNUAL DISCHARGE FREQUENCY SELECTED POINTS ON MAJOR TRIBUTARIES

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

SOUTH CENTRAL REGION APR. 1968 DALLAS, TEXAS



B-1

APPENDIX B
WATER QUALITY STANDARDS FOR COLORADO^{25/}

As Adopted May 15, 1968

Not Yet Approved by Federal Government

WATER QUALITY STANDARDS FOR COLORADO

The Second Session of the Forty-Fifth General Assembly of the State of Colorado passed Water Pollution Control Legislation for the State of Colorado as set out in Chapter 44, Session Laws 1966. In adopting this legislation, the following legislative declaration was made:

"Whereas the pollution of the waters of this state constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and other aquatic life, and impairs domestic, agricultural, industrial, recreational, and other beneficial uses of water; and whereas the problem of water pollution of this state is closely related to the problem of water pollution in adjoining states; and whereas it is the public policy of this state to conserve the waters of the state and to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and other aquatic life, and for domestic, agricultural, industrial, recreational, and other beneficial uses, and to provide that no wastes be discharged into any waters of the state without first being given the degree of treatment necessary to protect the beneficial uses of such water, it is hereby declared that the prevention, abatement, and control of the pollution of the waters of this state are affected with a public interest, and the provisions of this act are enacted in the exercise of the police powers of this state for the purpose of protecting the health, peace, and safety, and general welfare of the people of this state."

These standards are the foundation for the classification of the waters of the State of Colorado.

Standards are subject to revision as technical data, surveillance programs, and technological advances make such revisions desirable.

For purposes of enforcement of these standards, sampling will be done at a point where these standards can be evaluated.

The purposes of enforcement of water classification standards, sampling of the waters will be done at any point, except for areas immediately adjacent to outfalls and except as may be noted in the text of the standards. In such areas, cognizance will be given to the opportunity for admixture of waste effluents with receiving water.

Tests or analytical procedures to determine compliance with standards will, insofar as practicable and applicable, be made in accordance with the methods given in the latest edition of "Standard Methods For The Examination Of Water And Waste Water" published by the American Public Health Association, or in accordance with tests or analytical procedures that have been found to be equal or more applicable and satisfactory and accepted and approved by the Commission.

In areas where a body of water is classified for more than one use, the standards applicable to each use shall apply and in case of a conflict, the more restrictive standards shall prevail in each instance.

Where and when additional waters become available, hearings will be held on the possible classification or reclassification of such waters for further enhancement. The quality of water will be maintained as high as possible and in no case shall stream standards be violated.

It is expected that the present uses of the waters of Colorado will continue but if other uses develop, streams may be classified or reclassified after public hearings.

I. BASIC STANDARDS APPLICABLE TO ALL WATERS:

- A. All wastes capable of treatment or control prior to discharge into any waters of the state, shall receive secondary treatment with disinfection or its industrial waste equivalent, as determined by the State Water Pollution Control Commission. Lesser degrees of treatment or control may be permitted only where it can be demonstrated that the standards applicable to the classified use of the water can be attained. Greater degrees of treatment or control will be required where it can be demonstrated that it is necessary to comply with the standards applicable to the classified use of the water.
- B. Free from substances attributable to municipal, domestic, or industrial wastes, or other controllable sources that will either settle to form unsightly, putrescent, or odorous bottom deposits, or will interfere with the classified use of the water.
- C. Free from unsightly floating debris, oil, grease, scum, and other floating material attributable to municipal, domestic, or industrial wastes, or other controllable sources.
- D. Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will

produce odor in the water or produce an appreciable change in the existing color, taste, turbidity or other conditions that interfere with the classified use of the water.

- E. Free from high temperatures, biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to human or animal life.
- F. Radioactive materials attributable to municipal, industrial or other controllable sources will be minimum concentrations that are physically and economically feasible to achieve. In no case shall such materials in the stream exceed the limits established in the current edition of the U. S. Public Health Service Drinking Water Standards or the limits approved by the Federal Radiation Council, or, in the absence of any limits specified by the U. S. Public Health Service or the Federal Radiation Council, 1/30 of the 168-hour-week values for other radioactive substances specified in the National Bureau of Standards Handbook 69.

II. ADDITIONAL WATER QUALITY STANDARDS FOR BODIES OF WATER THAT HAVE BEEN CLASSIFIED FOR ANY OF THE FOLLOWING USES:

CLASS A.

The following standards shall apply to water withdrawn for treatment as a potable supply:

1. Bacteria: The annual average number of coliform bacteria at any sampling station shall not exceed the historical average by more than 20 percent and in no case shall the monthly average of the number of coliform bacteria exceed 5,000 per 100 milliliter (either MPN or MF count). All averages shall be computed logarithmically.
2. Dissolved Oxygen: Dissolved oxygen shall not be less than 4 milligrams per liter.
3. pH: The pH shall be maintained between 6.0 and 9.0.
4. Taste and Odor: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce taste or odor in the water.
5. Dissolved Solids: Total dissolved solids, annual volume weighted average, should be less than 500 milligrams per liter.

6. Selected Chemical Constituents: The following substances shall not be present in such amounts as to exceed the specified concentrations in a potable water supply according to the mandatory requirements of the latest edition of the U. S. Public Health Service Drinking Water Standards:

<u>Substance</u>	<u>Concentration - mg/l</u>
Arsenic	0.05
Barium	1.00
Cadmium	0.01
Chromium (Hexavalent)	0.05
Cyanide	0.20
Lead	0.05
Selenium	0.01
Silver	0.05

CLASS B.

1. The following standards shall apply to waters classified for fish and wildlife (Cold Water Fishery):
 - a. Dissolved Oxygen: In cold water fisheries, the dissolved oxygen content shall in no case go below 6 milligrams per liter.
 - b. pH: pH shall be maintained between 6.5 and 8.5. No controllable pH change will be permitted which will interfere with fish and aquatic life.
 - c. Turbidity: No turbidity shall exist in concentrations that will impair natural and developed fisheries.
 - d. Temperature: In cold water fisheries the temperatures shall not exceed 70°F. No controllable temperature change will be permitted which will interfere with the spawning and other aspects of fish life.
 - e. Toxic Material: Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to aquatic life.
 - f. Other Material: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce off-flavor in the flesh of fish.

2. The following standards shall apply to waters classified for fish and wildlife (Warm Water Fishery):
 - a. Dissolved Oxygen: In warm water fisheries, dissolved oxygen content shall in no case go below 5 milligrams per liter.
 - b. pH: pH shall be maintained between 6.5 and 8.5. No controllable pH change will be permitted which will interfere with fish and aquatic life.
 - c. Turbidity: No turbidity shall exist in concentrations that will impair natural and developed fisheries.
 - d. Temperature: In warm water fisheries the temperatures shall not exceed 90°F. No controllable temperature change will be permitted which will interfere with spawning and other aspects of fish life.
 - e. Toxic Material: Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to aquatic life.
 - f. Other Material: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce off-flavor in the flesh of fish.
3. The following standards shall apply to recreational waters classified for body contact sports such as, but not limited to, swimming and water skiing:
 - a. Bacteria: Total coliform bacteria shall not exceed 1,000 per 100 milliliters as a monthly average (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 2,400 per 100 milliliters in a single sample. In addition, the fecal coliform count shall not exceed 100 per 100 milliliters and the fecal streptococcus count shall not exceed 20 per 100 milliliters, both of these limits to be an average of five (5) consecutive samples within a month.
 - b. pH: pH shall be maintained between 6.5 and 8.5.

CLASS C:

The following standards shall apply to waters classified for industrial uses:

1. Dissolved Oxygen: Dissolved oxygen content shall not go below 3 milligrams per liter.
2. pH: pH shall be maintained between 5.0 and 9.0.
3. Turbidity: No turbidity shall exist in concentrations that will interfere with established levels of treatment.
4. Temperature: The temperature shall not exceed 93°F.

CLASS D:

1. The following standards shall apply to waters classified for irrigation:

- a. Total Dissolved Solids (Salt) Concentration:

A time-weighted monthly mean at a monitoring station which exceeds the time-weighted monthly mean for a base period established by the Commission by more than two standard deviations shall be subject to review by the Commission.

- b. Sodium Adsorption Ratio:

A time-weighted monthly mean at a monitoring station which exceeds the time-weighted monthly mean for a base period established by the Commission by more than two standard deviations shall be subject to review by the Commission.

- c. Toxic Material:

Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, industrial wastes, or other controllable sources in concentrations or combinations which are harmful to crop life.

2. The following standards shall apply to waters classified for livestock watering:

- a. Soluble Salts: The soluble salts shall not exceed 3,000 milligrams per liter.

CLASSIFICATION OF
INTERSTATE AND INTRASTATE STREAMS
IN COLORADO

General Provisions:

1. Basic Standards will apply to all waters, public and private, including natural and artificial lakes and reservoirs, whether classified or not.

2. Classification standards shall apply to the full width of the body of water so classified.

3. The classification of waters shall not be construed as an action to supplant or interfere with decreed uses of the water. Nothing herein shall be construed to require the delivery of water from one basin to another or from one state to another or to affect the provisions of any interstate compact or U. S. Supreme Court Decisions.

4. Stream standards are based on historical stream flow data.

5. Owners (municipalities, irrigation companies, and industries) of specific bodies of water may utilize the waters as desired provided that the water quality standards set for that body of water are maintained.

Table B-1

WATER QUALITY STANDARDS SUMMARY**

Class	Bacteria	D.O. PPM	pH	Turb.	T.D.S.	Toxic	Temp. Deg. F	S.A.R.	S.C.C.	Taste & Odors
A	< 5000/100 ml.*	4	6.0 - 9.0	--	<500 mg/l*	Free From*	--	--	*	Free From*
A, B ₁	< 5000/100 ml.*	6	6.5 - 8.5	*	<500 mg/l*	Free From* (Aquatic)	70°	--	*	Free From*
A, B ₁ , B ₃	< 1000/100 ml.*	6	6.5 - 8.5	*	<500 mg/l*	Free From*	70°	--	*	Free From*
A, B ₂	< 5000/100 ml.*	5	6.5 - 8.5	*	<500 mg/l*	Free From* (Aquatic)	93°	--	*	Free From*
A, D ₁	< 5000/100 ml.*	4	6.0 - 9.0	--	<500 mg/l*	Free From*	--	--	*	Free From*
B ₁	--	6	6.5 - 8.5	*	--	Free From* (Aquatic)	70°	--	--	Free From* (Aquatic)
B ₁ , D ₁	--	6	6.5 - 8.5	*	*Agricultural	Free From* (Aquatic & Crops)	70°	*	--	Free From* (Aquatic)
B ₂ , B ₃	< 1000/100 ml.*	5	6.5 - 8.5	*	--	Free From* (Aquatic)	93°	--	--	Free From* (Aquatic)
B ₂ , C	--	5	6.5 - 8.5	*	--	Free From* (Aquatic)	93°	--	--	Free From* (Aquatic)
B ₂ , C, D ₁	--	5	6.5 - 8.5	*	*Agricultural	Free From* (Aquatic & Crops)	93°	*	--	Free From* (Aquatic)
B ₂ , D ₁	--	5	6.5 - 8.5	*	*Agricultural	Free From* (Aquatic & Crops)	93°	*	--	Free From* (Aquatic)
C, D ₁	--	3	5.0 - 9.0	*	--	Free From* (Crops)	93°	--	--	--
D ₁	--	--	--	--	*Agricultural	Free From* (Crops)	--	*	--	--

* Refer to standard for specific language < Less than

**Basic Standards apply to all waters

LEGEND:

CLASS	STREAM USE
A	Public Water Supply
B ₁	Cold Water Fishery
B ₂	Warm Water Fishery
C	Industrial Uses
D ₁	Irrigation



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WATER QUALITY CONTROL DISTRICT
TERRITORIAL ARIZONA PROJECT
ARKANSAS RIVER SUBBASIN-CO-24500

STREAM USE CLASSIFICATION MAP

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTHERN REGIONAL OFFICE
JAN 1968
SALAS, TEXAS
FIGURE B-1

NO SCALE

Table B-2
Stream Use Classification

Area No.	Area	From	To	Quality Class
1	Main Stem of Arkansas River	Source above Leadville	State of Colorado river flow measuring station 0.7 mile upstream from First Street Bridge in Canon City and near Sand Creek	A, B ₁
2	Main Stem of Arkansas River	State of Colorado river flow measuring station 0.7 mile upstream from First Street Bridge in Canon City and near Sand Creek	City of Pueblo's south side water treatment plant dam	A, B ₂
3	Main Stem of Arkansas River	City of Pueblo's south side water treatment plant dam	Intersection with State Highway #167 at Fowler	C, D ₁
4	Main Stem of Arkansas River	Intersection with State Highway #167 at Fowler	Diversion point for Rocky Ford Canal	A, D ₁
5	Main Stem of Arkansas River	Diversion point for Rocky Ford Canal	Town of Holly	C, D ₁
6	Main Stem of Arkansas River	Town of Holly	Colorado-Kansas State Line	B ₂ , D ₁
7	Tennessee Creek, Lake Fork Creek, Lake Creek, Clear Creek, Cottonwood Creek, South Arkansas River and Beaver Creek including Turquoise Lake and Otero Reservoir	Sources	Confluences with Arkansas River	A, B ₁
8	Adobe, Mineral, and Newlin Creeks	Sources	Mouths	A, B ₁
9	Fountain Creek, including all tributaries and public water supply reservoirs	Sources	To confluence with Monument Creek	A, B ₁
10	Fountain Creek	Confluence with Monument Creek	Confluence with Arkansas River	D ₁
11	Apishapa River	Sources	Intersection with U. S. Highway 85-87 near the Town of Aguilar	B ₁
12	Apishapa River	Intersection with Colorado U. S. Highway 85-87 near Town of Aguilar	Confluence with Arkansas River	C, D ₁
13	Cucharas River	Source	Point of diversion for Walsenburg's public water supply	A, B ₁
14	Cucharas River	Point of diversion for Walsenburg's public water supply	Confluence with Huerfano River	C, D ₁
15	Huerfano River	Source	Intersection with U. S. Highway #85 & 87	B ₁
16	Huerfano River	Intersection with U.S. Highway #85 & 87	Confluence with Arkansas River	C, D ₁
17	Purgatoire River including Whisky Creek and North and Monument Lakes	Sources	Point of diversion for Town of Trinidad's public water supply	A, B ₁
18	Purgatoire River	Point of diversion for Town of Trinidad's public water supply	Town of Trinidad	B ₁ , C
19	Purgatoire River	Town of Trinidad	Confluence with Arkansas River	C, D ₁
20	Greenhorn River	Source	Town of Rye	A, B ₁
21	Greenhorn River	Town of Rye	Confluence with St. Charles River	C, D ₁
22	St. Charles River, including Middle St. Charles River	Sources	Confluence of St. Charles and Little St. Charles Rivers	A, B ₁
23	St. Charles River	Confluence of St. Charles and Little St. Charles River	Confluence with Arkansas River	C, D ₁

APPENDIX C
COST ANALYSES 26-30/

WATER QUALITY CONTROL BY FLOW REGULATION
AND ADVANCED WASTE TREATMENT

Water Quality Control in the Arkansas River Below Pueblo

It has been assumed that direct releases to the river from Pueblo reservoir will decrease to zero by the year 2040 due to satisfaction of increasing municipal and industrial water demands from the reservoir and stream system above the reservoir. After 2030, flow in the river below Pueblo must be supplemented by controlled releases from reservoirs on tributary streams.

Method A - Storage for Flow Regulation

Construction Schedule

<u>Reservoir</u>	<u>Year</u>	<u>Yield Needed (mgd)</u>
Pleasant View	2030	12.6
Welton	2032	12.5
Apishapa	2034	21.5
Timpas	2038	17.9
Adobe	2055	11.6

Pleasant View Reservoir

Years use during study period 2030 - 2070

First Cost \$ 4,500,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 157,500
Annual operation and maintenance costs	22,500
Annual cost 100 yr. period	\$ 175,000

Capitalize 40 years	\$ 3,886,500
Discount 55 yr. (initial const. to 1970)	669,300
Amortize (100 yr. @ 3½%)	22,700
Annual cost during study period	22,700

Welton Reservoir

Years use during study period 2032 - 2070

First Cost \$10,000,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 338,800
Annual operation and maintenance cost	<u>50,000</u>
Annual cost 100 yr. period	\$ 388,800

Capitalize 38 years	\$ 8,414,800
Discount 57 years (initial Const. to 1970)	<u>1,359,300</u>
Amortize (100 yr. @ 3½%)	46,000

Annual cost during study period \$ 46,000

Apishapa Reservoir

Years use during study period 2034 - 2070

First Cost \$ 6,764,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 229,200
Annual operation and maintenance cost	<u>33,800</u>
Annual cost 100 yr. period	\$ 263,000

Capitalize 36 years	\$ 5,533,500
Discount 59 yr. (initial Const. to 1970)	<u>838,500</u>
Amortize (100 yr. @ 3½%)	28,400

Annual cost during study period 28,400

Timpas Reservoir

Years use during study period 2038 - 2070

First Cost \$ 2,850,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 96,600
Annual operation and maintenance cost	<u>14,300</u>
Annual cost 100 year period	\$ 110,900

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Capitalize 32 years	\$ 2,186,100
Discount 63 years (initial Constr. to 1990)	291,500
Amortize (100 yr. @ 3½%)	9,900
Annual cost during study period	\$ 9,900

Adobe Reservoir

Years use during study period	2055 - 2070
First Cost	\$ 4,400,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 149,100
Annual operation and maintenance costs	22,000
Annual cost 100 year period	\$ 171,100
Capitalize 15 years	\$ 2,006,100
Discount 80 years (initial Constr. to 1970)	155,300
Amortize (100 yr. @ 3½%)	5,300
Annual cost during study period	\$ 5,300

Summary of Annual Cost - Method A

<u>Reservoir</u>	<u>Annual Cost</u>
Pleasant View	\$ 22,700
Welton	46,000
Apishapa	28,400
Timpas	9,900
Adobe	5,300
Total Annual Cost	\$ 112,300

Method B - Storage for Flow Regulation and Advanced Waste Treatment

Use Pueblo, Pleasant View, and Welton Reservoirs for flow regulation with waste treatment facilities capable of 93 percent BOD removal.

Advanced waste treatment (coagulation-sedimentation) would not be required until the year 2030. Releases from Pueblo Reservoir would provide adequate flow for quality control to 2030.

Construction Schedule

<u>Facilities</u>	<u>Year Needed</u>
140 mgd coagulation-sedimentation waste treatment process	2030
Pleasant View Reservoir (12.6 mgd yield)	2035
25 mgd coagulation-sedimentation waste treatment process	2050
Welton Reservoir (6 mgd yield)	2060
<u>2030 Facilities</u>	
Years use during study period	2030 - 2070
First Cost	\$14,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 474,400
Annual operation and maintenance costs	823,400
Annual cost 100 yr. period	\$ 1,297,800
Capitalize 40 years	\$28,822,100
Discount 60 years	4,229,800
Amortize (100 yr. @ 3½%)	143,300
Annual cost during study period	\$ 143,300
<u>2035 Facilities</u>	
Years use during study period	2035 - 2070
First Cost	\$ 4,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 152,500
Annual operation and maintenance cost	22,500
Annual cost 100 yr. period	\$ 175,000

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Capitalize 35 years	\$ 3,626,700
Discount 65 yr. (initial Constr. to 1970)	453,600
Amortize (100 yr. @ 3½%)	15,400
Annual cost during study period	\$ 15,400

2050 Facilities

Years use during study period	2050 - 2070
First Cost	\$ 2,500,000
Annual Cost:	

Amortize first cost (100 yr. @ 3½%)	\$ 84,700
Annual operation and maintenance cost	147,000
Annual cost for 100 yr.	\$ 231,700
Capitalize 20 years	\$ 3,368,800
Discount 80 years	260,800
Amortize (100 yr. @ 3½%)	8,900
Annual cost during study period	\$ 8,900

2060 Facilities

Years use during study period	2060 - 2070
First Cost	\$ 6,000,000
Amortize first cost (100 yr. @ 3½%)	\$ 203,300
Annual operation and maintenance cost	30,000
Annual cost 100 yr. period	\$ 233,300
Capitalize 10 years	\$ 1,964,900
Discount 90 yr. (initial Constr. to 1970)	110,500
Amortize (100 yr. @ 3½%)	3,700
Annual cost during study period	\$ 3,700

Summary of Annual Cost - Method B

<u>Facility</u>	<u>Year Needed</u>	<u>Annual Cost</u>
140 mgd treatment	2030	\$ 143,300
Pleasant View Reservoir	2035	15,400
25 mgd treatment	2050	8,900
Welton Reservoir	2060	3,700
Total Annual Cost		\$ 171,300

Method C - Advanced Waste Treatment

Provide waste treatment facilities to increase BOD removal from 90 percent to 99 percent.

Advanced waste treatment (coagulation-sedimentation and adsorption) would not be required until the year 2030. Releases from Pueblo Reservoir would provide adequate flow for quality control to 2030.

Construction Schedule

<u>Capacity Treatment Facilities (mgd)</u>	<u>Year Needed</u>
140	2030
25	2050

2030 Facilities

Years use during study period	2030 - 2070
-------------------------------	-------------

First Cost	\$35,000,000
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Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 1,185,900
Annual operation and maintenance cost	<u>1,547,400</u>
Annual cost for 100 yr. period	\$ 2,733,300

Capitalize 40 years	\$60,702,300
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Discount 60 years	8,908,400
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Amortize (100 yr. @ 3½%)	301,800
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Annual cost for study period	\$ 301,800
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2050 Facilities

Years use during study period	2050 - 2070
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First Cost	\$ 6,250,000
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Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 211,800
Annual operation and maintenance cost	<u>276,300</u>
Annual cost 100 yr. period	\$ 488,100

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Capitalize 20 years	\$ 7,096,700
Discount 80 years	549,400
Amortize (100 yr. @ 3½%)	18,600
Annual cost during study period	18,600

Summary of Annual Cost - Method C

<u>Years Needed</u>	<u>Plant Size</u>	<u>Annual Cost</u>
2030	140 mgd	\$ 301,800
2050	25 mgd	<u>18,600</u>
		\$ 320,400

Table C-1

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COMPARISON OF COSTS^{a/}
FOR
WATER QUALITY CONTROL^{b/} IN THE ARKANSAS RIVER BELOW
PUEBLO BY FLOW REGULATION AND ADVANCED WASTE TREATMENT

<u>Method of Control</u>		<u>Annual Cost During Study Period</u>
<u>Method A</u>		
Flow Regulation		
Pueblo Reservoir	1975 - 2030)	
Pleasant View Reservoir	2030 - 2070)	
Welton Reservoir	2032 - 2070)	\$112,300
Apishapa Reservoir	2034 - 2070)	
Timpas Reservoir	2038 - 2070)	
Adobe Reservoir	2055 - 2070)	
<u>Method B</u>		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2030)	
93% BOD removal	2030 - 2070)	
	)	
Flow Regulation	)	\$171,300
Pueblo Reservoir	1975 - 2030)	
Pleasant View Reservoir	2035 - 2070)	
Welton Reservoir	2060 - 2070)	
<u>Method C</u>		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2030)	
99% BOD Removal	2030 - 2070)	
	)	
Flow Regulation	)	\$320,400
Pueblo Reservoir	1975 - 2030)	

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

Water Quality Control in Fountain Creek

Two reservoirs, Ute Pass and Fountain Creek could be used to provide storage for supplementing streamflow in Fountain Creek. However, even with supplemental flow from these reservoirs, waste treatment would be required for 90 percent BOD removal from 1970 to 2010, 93 percent BOD removal from 2010 to 2060, and 99 percent removal from 2060 to 2070. Computations below compare cost of storage with costs of additional facilities required if storage is not provided. Total costs for waste disposal have not been computed.

Method A - Storage for Flow Regulation

Ute Pass Reservoir

Years use during study period	1970 - 2070
Yield	26.9 mgd
First Cost	\$13,000,000
Annual Cost:	
Amortize first cost (100 yrs.@ 3½%)	\$ 440,500
Annual operation and maintenance	65,000
Annual cost for study period	\$ 505,500

Fountain Creek Reservoir

Years use during study period	1990 - 2070
Yield	14.1 mgd
First Cost	\$26,600,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 901,300
Annual operation and maintenance	133,000
Annual cost for 100 year period	\$ 1,034,300
Capitalize 80 years	\$29,361,100
Discount 15 years (initial Constr. to 1970)	18,172,800
Amortize (100 yr. @ 3½%)	615,800
Annual cost for study period	\$ 615,800

Summary of Annual Cost - Method A

Ute Pass	\$ 505,500
Fountain Creek	615,800
Total Annual Cost	\$ 1,121,300

Method - B

Provide waste treatment facilities for 99 percent BOD removal.

With supplemental flows provided by Ute Pass and Fountain Creek Reservoirs or by pumping water from the Arkansas River, waste treatment would be required for 90 percent BOD removal from 1970 to 2010, 93 percent BOD removal from 2010 to 2060, and 99 percent removal from 2060 to 2070. Without the supplemental flows, waste treatment facilities for 99 percent BOD removal would be required for the entire study period. The cost of increasing the degree of waste treatment can be considered an alternative to providing quality control storage.

-Increase From 90 to 99 Percent BOD removal-

1970 (Add 70 mgd coagulation-sedimentation process)

Years use during study period 1970 - 2070

Capital Cost \$ 7,000,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 237,200
Annual operation and maintenance	<u>411,700</u>
Annual cost during study period	\$ 648,900

1970 (Add 70 mgd adsorption process)

Years use during study period 1970 - 2070

Capital Cost \$10,500,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 355,800
Annual operation and maintenance	<u>362,000</u>
Annual cost during study period	\$ 717,800

1990 (Add additional 30 mgd coagulation-sedimentation process)

Years use during study period 1990 - 2070

Capital Cost \$ 3,000,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 101,700
Annual operation and maintenance	<u>176,400</u>
Annual cost for 100 year period	\$ 278,100

Capitalize 80 years	\$ 7,894,500
Discount 20 years	4,164,100
Amortize (100 yr. @ 3½%)	141,100

Annual cost during study period	\$ 141,100
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1990 (Add additional 30 mgd adsorption process)

Years use during study period	1990 - 2070
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Capital Cost	\$ 4,500,000
--------------	--------------

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 152,500
Annual operation and maintenance	<u>155,200</u>
Annual cost 100 year period	\$ 307,700

Capitalize 80 years	\$ 8,734,800
Discount 20 years	4,607,400
Amortize (100 yr. @ 3½%)	156,100

Annual cost during study period	\$ 156,100
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-Increase From 93 to 99 Percent BOD Removal-

2010 (Add additional 40 mgd adsorption process)

Years use during study period	2010 - 2070
-------------------------------	-------------

Capital Cost	\$ 6,000,000
--------------	--------------

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 203,300
Annual operation and maintenance	<u>206,900</u>
Annual cost 100 year period	\$ 410,200

Capitalize 60 years	\$10,769,200
Discount 40 years	2,996,300
Amortize (100 yrs. @ 3½%)	101,500

Annual cost during study period	\$ 101,500
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2030 (Add additional 40 mgd adsorption process)

Years use during study period	2030 - 2070
Capital Cost	\$ 6,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 203,300
Annual operation and maintenance	<u>206,900</u>
Annual cost 100 year period	\$ 410,200
Capitalize 40 years	\$ 9,109,900
Discount 60 years	<u>1,336,900</u>
Amortize (100 yr. @ 3½%)	45,300
Annual cost during study period	\$ 45,300

2050 (Add additional 25 mgd adsorption process)

Years use during study period	2050 - 2070
Capital Cost	\$ 3,750,000
Annual Cost:	
Amortize first cost (100 yrs. @ 3½%)	\$ 127,000
Annual operation and maintenance	<u>129,300</u>
Annual cost 100 year period	\$ 256,300
Capitalize 20 years	\$ 3,726,400
Discount 80 years	<u>208,500</u>
Amortize (100 yr. @ 3½%)	9,800
Annual cost during study period	\$ 9,800

Summary of Annual Cost - Method B

1970 facilities	\$ 1,366,700
1990 facilities	297,200
2010 facilities	101,500
2030 facilities	45,300
2050 facilities	<u>9,800</u>
Total Annual Cost	\$ 1,820,500

Discussion

Costs for land disposal of wastes are also presented in this appendix. If waste is discharged to land rather than Fountain Creek, treatment for only 90 percent BOD removal would be adequate for the entire study period. If control methods above are compared to land disposal, it is necessary to determine the cost of increasing the degree of waste treatment from 90 percent to the levels assumed in the above analyses. This cost added to costs determined above, will be comparative with control methods requiring only 90 percent waste treatment.

-Increase From 90 to 93 Percent BOD Removal-2010 (Add 140 mgd coagulation-sedimentation process)

Capital Cost	\$14,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 474,400
Annual operation and maintenance cost	823,400
Annual cost for 100 year period	\$ 1,297,800
Capitalize 60 years	\$34,072,000
Discount 40 years	9,481,100
Amortize (100 yrs. @ 3½%)	321,300
Annual cost during study period	\$ 321,300

-Increase From 93 to 99 Percent Removal-2060 (Add 88 mgd coagulation -sedimentation process)

Capital Cost:	\$ 8,800,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	\$ 298,200
Annual operation and maintenance cost	517,600
Annual cost for 100 year period	\$ 815,800
Capitalize 10 years	\$ 6,871,000
Discount 90 years	386,300
Amortize (100 yrs. @ 3½%)	13,100
Annual cost during study period	\$ 13,100

2060 (Add 88 mgd adsorption process)

Capital Cost:	\$13,200,000
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Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 447,300
Annual operation and maintenance cost	<u>455,200</u>
Annual cost for 100 year period	\$ 902,500

Capitalize 10 years	\$ 7,601,200
Discount 90 years	427,300
Amortize (100 yrs. @ 3½%)	14,500

Annual cost during study period	\$ 14,500
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Summary of Annual Costs:

2010 facilities	\$ 321,300
2060 facilities	<u>27,600</u>
	\$ 348,900

COMPARISON OF COSTS^{a/}
FOR
WATER QUALITY CONTROL^{b/} IN FOUNTAIN CREEK BY
FLOW REGULATION AND ADVANCED WASTE TREATMENT

<u>Method of Control</u>		<u>Annual Cost</u> <u>During Study</u> <u>Period</u>
<u>Method A</u>		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2010)	
93% BOD Removal	2010 - 2060)	
99% BOD Removal	2060 - 2070)	
(Flow exceeding 140 mgd)	)	
	)	\$ 1,470,200
Supplemental Flows	)	
Ute Pass Reservoir	1970 - 2070)	
Fountain Creek Reservoir	1990 - 2070)	
<u>Method B</u>		
Advanced Waste Treatment		
99% BOD Removal	1970 - 2070	\$ 2,169,400

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

WATER QUALITY CONTROL BY LAND DISPOSAL OF WASTES

Through the year 2020, waste produced at Colorado Springs can be transported by pipeline to the vicinity of Pueblo re-aerated to restore the dissolved oxygen concentration to 4 mg/l and discharged to the Arkansas River. Releases from Pueblo Reservoir will be adequate to dilute these wastes and all other wastes to be discharged to the river below the reservoir. However, it has been assumed that releases from Pueblo Reservoir will be reduced to zero by the year 2040 due to increasing uses of water in and above the reservoir for water supplies. After the year 2020 wastes from Colorado Springs and Pueblo can no longer be discharged to the river unless the flow is supplemented. Facilities were designed to transport wastes from

these cities directly to farming areas for irrigation. Only major transmission pipelines were designed with the assumption that distribution to individual farms would be the responsibility of farm owners. (See figure C-1)

Design Criteria:

Use oxygen transfer rates at 23°C

Maintain D.O. in pipelines above 1.0 mg/l

Maintain D.O. above 4.0 mg/l where waste is discharged to the stream system

Maintain 4.0 mg/l D.O. in waste treatment plant effluents

Provide waste treatment plants capable of removing 90 percent of the BOD load

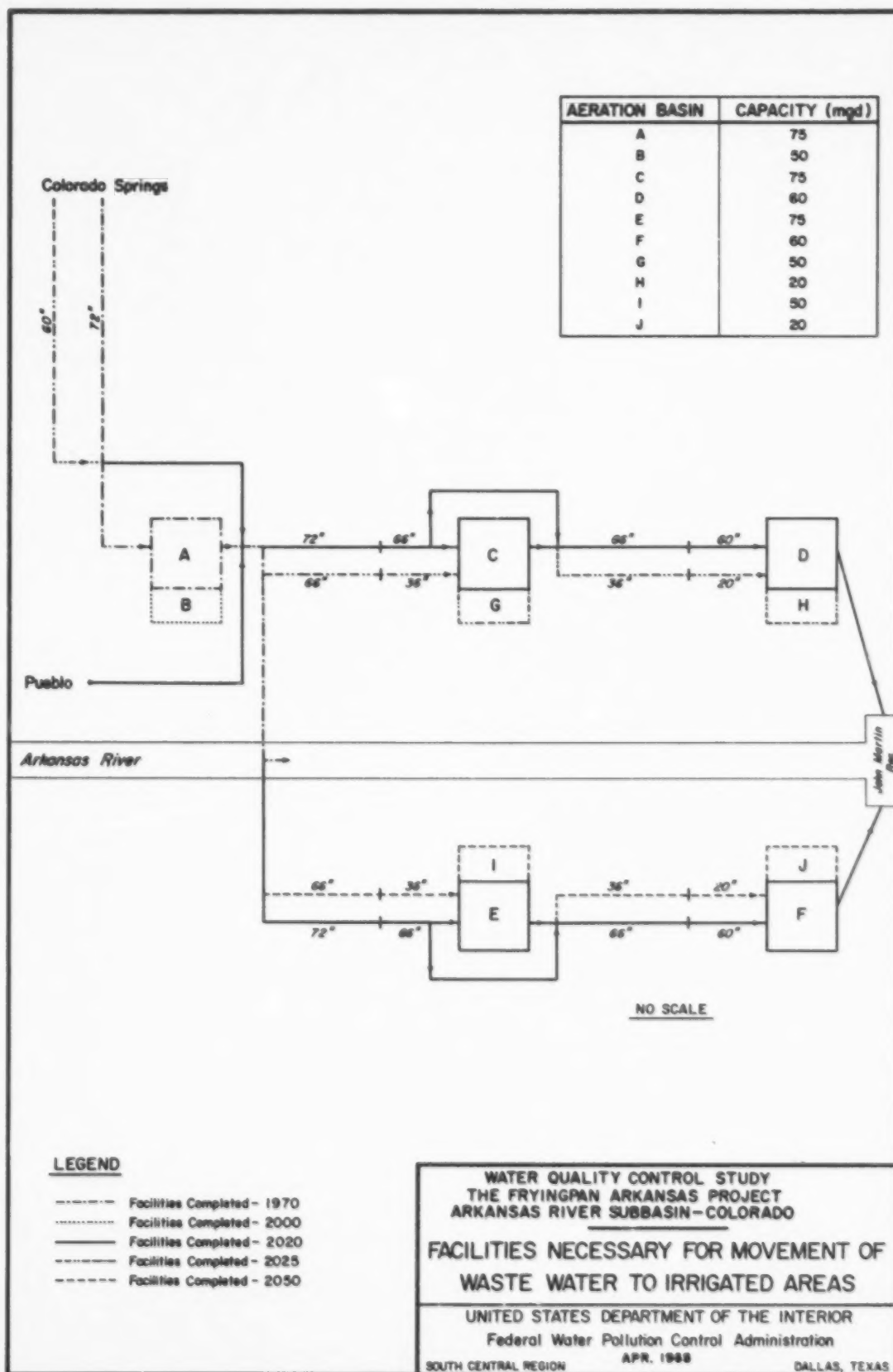
Detention in Aeration Basins - 2 hours

Pipeline Capacity: (See figure C-1)

<u>Pipeline Diameter (inches)</u>	<u>Capacity (mgd)</u>	<u>Velocity (fps)</u>
72	120	4
72	115	3.8
66	90	3.8
66	80	3.4
60	60	3.4
36	55	3.4
30	35	3.4

Aeration Basin Capacity: (See figure B-1)

<u>Basin</u>	<u>Size LXWXD (feet)</u>	<u>No. Surface Aerators</u>	<u>Aerator Rotor Horsepower</u>	<u>Flow (mgd)</u>
A	291X291X10	9	6.8	75
B	291X194X10	6	6.8	50
C	291X291X10	9	6.8	75
D	258X248X10	9	4.6	60
E	291X291X10	9	6.8	75
F	258X258X10	9	4.6	60
G	291X194X10	6	6.8	50
H	258X86X10	3	4.6	20
I	291X194X10	6	6.8	50
J	258X86X10	3	4.6	20



1970 Facilities

Years use during study period 1970 - 2070

First Cost:

45 miles of 72 inch pipeline	\$18,000,000
Aeration Basin A	<u>11,250,000</u>
	\$29,250,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 991,100
Annual operation and maintenance costs	<u>150,000</u>
Annual cost for study period	\$ 1,141,100

2000 Facilities

Years use during study period 2000 - 2070

First Cost:

Aeration basin B	\$ 7,500,000
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Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 254,100
Annual operation and maintenance cost	<u>100,000</u>
Annual cost for 100 year period	\$ 354,100

Capitalize 70 years	\$ 9,734,100
Discount 30 years	3,729,000
Amortize (100 yr. @ 3½%)	<u>126,400</u>

Annual cost during study period	\$ 126,400
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2020 Facilities

Years use during study period 2020 - 2070

First Cost:

60 miles of 72 inch pipeline	\$24,000,000
80 miles of 66 inch pipeline	28,000,000
20 miles of 60 inch pipeline	5,900,000
Aeration basin C	11,250,000
Aeration basin D	9,000,000
Aeration basin E	11,250,000
Aeration basin F	<u>9,000,000</u>
	\$98,400,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 3,334,100
Annual operation and maintenance	<u>540,000</u>
Annual cost for 100 year period	\$ 3,874,100
Capitalize 50 years	\$95,116,000
Discount 50 years	19,219,900
Amortize (100 yr. @ 3½%)	<u>651,200</u>
Annual cost during study period	\$ 651,200

2025 Facilities

Years use during study period 2025 - 2070

First Cost:

30 miles of 66 inch pipeline	\$10,500,000
45 miles of 60 inch pipeline	13,275,000
40 miles of 36 inch pipeline	5,120,000
10 miles of 30 inch pipeline	1,030,000
Aeration basin G	7,500,000
Aeration basin H	<u>3,000,000</u>
	\$40,425,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 1,369,700
Annual operation and maintenance cost	<u>140,000</u>
Annual cost for 100 year period	\$ 1,509,700
Capitalize 45 years	\$35,438,100
Discount 55 years	6,102,600
Amortize (100 yr. @ 3½%)	<u>206,800</u>
Annual cost during study period	\$ 206,800

2050 Facilities

Years use during study period 2050 - 2070

First Cost:

30 miles 66 inch pipeline	\$10,500,000
40 miles 36 inch pipeline	5,120,000
10 miles 30 inch pipeline	1,030,000
Aeration basin I	7,500,000
Aeration basin J	<u>3,000,000</u>
	\$27,150,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	\$ 919,900
Annual operation and maintenance cost	<u>140,000</u>
Annual cost for 100 year period	\$ 1,059,900
Capitalize 20 years	\$15,410,300
Discount 80 years	<u>1,192,900</u>
Amortize (100 yr. @ 3½%)	40,420
Annual cost during study period	\$ 40,420

Summary of Annual Costs:

1970 facilities	\$ 1,141,100
2000 facilities	<u>126,400</u>
2020 facilities	651,200
2025 facilities	<u>206,800</u>
2050 facilities	40,400
	\$ 2,165,900

COMPARISON OF COSTS^{a/}
FOR
WATER QUALITY CONTROL^{b/} IN THE STUDY AREA

<u>Method of Control</u>	<u>Annual Cost During Study Period (1970-2070)</u>	
Flow Regulation and Advanced Waste Treatment		
Fountain Creek (Method A) ^{c/}	\$ 1,470,200	\$1,582,500
Ark. River below Pueblo (Method A) ^{d/}	112,300	
Land Disposal		\$2,165,900
Advanced Waste Treatment		
Fountain Creek (Method B) ^{c/}	\$ 2,169,400	\$2,489,800
Ark. River below Pueblo (Method C) ^{d/}	320,400	

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

c/ From Table C-2

d/ From Table C-1